

**LUNAR PROSPECT
TECHNICAL DESIGN**

September 6 & 7, 1995

Wednesday

LOCKHEED MARTIN



**LOCKHEED MARTIN MISSILES & SPACE CO
SPACE SYSTEMS DIVISION
SUNNYVALE, CA 94089-3504**

1.0 WELCOME

M. SAUNDERS / F. MARTIN

Technical Design Review

September 6, 1995

■ Introduction

LOCKHEED MARTIN

Agenda

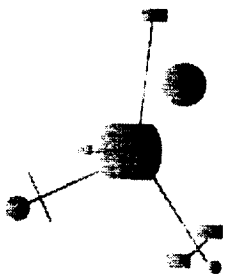
- | | | |
|---|-----------------------|------|
| 1. Welcome/Introduction | M. Saunders/F. Martin | 8:00 |
| 2. Ames Mission Management
Office Rolls & Responsibilities | S. Hubbard | 8:15 |
| 3. Program Overview/Requirements/
Description | A. Binder | 8:30 |

Break

- | | | |
|-------------------|--------------|-------|
| 4. Project Status | A. Binder | 10:00 |
| 5. Management | T. Dougherty | 11:00 |

Lunch

- | | | |
|-------------------------------|-----------|------|
| 6. Science Goals & Objectives | A. Binder | 1:00 |
| 7. Science Instruments | A. Binder | 2:00 |
| 8. Systems Requirements | M. Smith | 4:00 |



■ Introduction

Technical Design Review

September 7, 1995

LOCKHEED MARTIN

Agenda

- | | | |
|--|--------------|-------|
| 9. Spacecraft Subsystems | T. Dougherty | 8:00 |
| 10. Systems Assembly, Integration & Test | K. Foster | 11:00 |

Lunch

- | | | |
|---------------------|-----------------------|------|
| 11. Launch Vehicle | R. Lynch | 1:00 |
| 12. Ground System | T. Bridges/M. Stewart | 2:00 |
| 13. Operations | A. Binder | 2:20 |
| 14. SR&QA | R. Fullerton | 2:30 |
| 15. Opportunities | A. Binder | 2:50 |
| 16. Risk Management | T. Dougherty | 3:10 |
| 17. Program Costs | T. Dougherty | 3:30 |
| 18. Closing Remarks | A. Binder | 4:00 |

2.0 AMES MISSION MANAGEMENT OFFICE ROLLS & RESPONSIBILITIES

S. Hubbard

3.0 PROGRAM OVERVIEW/REQUIREMENTS/ DESCRIPTION

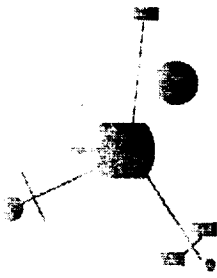
A. BINDER

Programmatic Goals

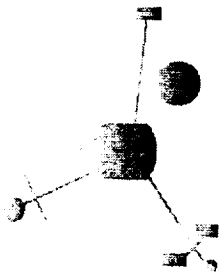
Project Overview

LOCKHEED MARTIN

- Demonstrate “**Faster, Better, Cheaper**” goals of Discovery
- Demonstrate utility of small, simple spacecraft for lunar and planetary exploration
- Satisfy or address most of remaining LExSWG lunar orbit mapping objectives
 - Objectives based on Apollo results
 - Galileo and Clementine addressed spectral imaging and topographic mapping
 - Lunar Prospector will provide global maps of polar ice deposits, composition, gravity and magnetic fields and gas release events
- Improve understanding of origin, evolution, current state and resources of the Moon
- Serve as catalyst for renewed lunar exploration via education and outreach programs



- Lunar Prospector started 7 years ago by SSI and LEI as private effort to demonstrate what is now “Faster, Better, Cheaper”
- Gained early support
 - Congress
 - NASA donated Apollo 17 GRS
 - Proton launch
 - “Grass roots” support from number of sources
- Defined science goals and payload and assembled science team
- Recruited engineering team
- Defined mission requirements, operations, time-line, etc.
- Conducted \$75k spacecraft definition study with OMNI Systems
- Sought support from aerospace and commercial communities
- Selected to be first SEI mission
- PI teamed with Lockheed and Ames to propose to Discovery



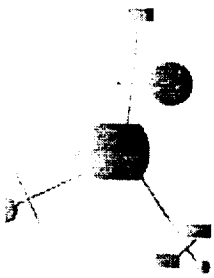
Science Selection Rational

■ Project Overview

LOCKHEED MARTIN



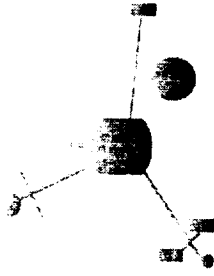
- Satisfy high priority LExSWG lunar orbit mapping objectives
- Omni directional
- No sequencing
- Low mass
- Low data rates
- Low power
- No new development
- Use commercial experience/parts where possible
- High reliability
- Simple instruments



Science Payload



- Gamma-Ray Spectrometer (GRS)
 - Elemental composition
 - Indium, BGO detector
- Neutron Spectrometer (NS)
 - Polar water ice deposits
 - H distribution in regolith
- Alpha Particle Spectrometer (APS)
 - Gas release event frequency and locations
- Magnetometer (MAG) and Electron Reflectometer (ER)
 - Magnetic fields
 - Induced magnetic moment/lunar core
- Doppler Gravity Experiment (DGE)
 - Gravity field
 - Internal structure/lunar core



Science Team



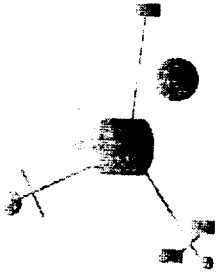
- Science team consists of PI and 6 Co-Is divided into 3 Experiment Groups
- Spectrometer Group
 - Dr. William Feldman, LANL: Group Leader, Co-I, NS
 - Dr. Robert McMurray, Jr., Ames: Acting Co-I, GRS
 - Dr. Alan Binder, Lockheed: PI, APS
- Magnetometer Group
 - Dr. Robert Lin, UC Berkeley: Group Leader, Co-I, ER
 - Dr. Mario Acuna, GSFC: Co-I, MAG
 - Dr. Lon Hood, U Arizona: Co-I, MAG
- Gravity Group
 - Dr. Alexander Konopliv, JPL: Co-I, DGE

Commitments

■ Project Overview

LOCKHEED MARTIN

- Commitments in place:
 - Ames
 - LMMS
 - All Co-Is
 - GSFC trajectory
 - Archiving
 - Most outreach and education support
- Outstanding commitments:
 - Code O tracking (verbal but no written)
 - Code S go-ahead to C/D and E



Experiment Durations

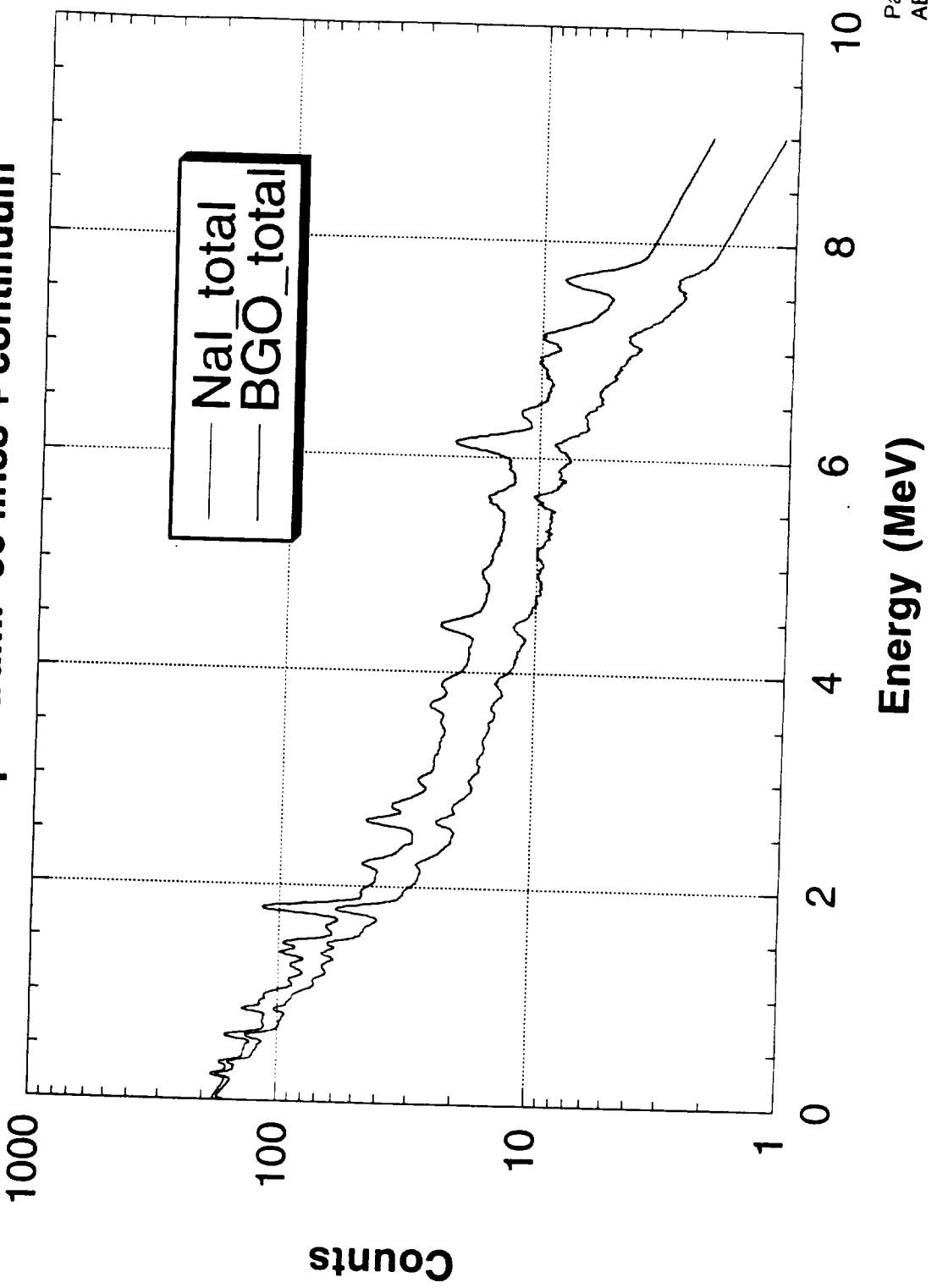
- GRS elemental composition mapping
 - Th, U, K, Ti: 1-3 months
 - O, Fe: 6-9 months
 - Al, Ca, Si, Mg: 1.2-1.8 years
- NS mapping
 - Polar water ice: 1 month
 - Regolith H distribution: 5 months
- APS gas release event mapping: As long as possible
- MAG/ER magnetic mapping: 6 months
- DGE gravity mapping: 2 months of DSN support

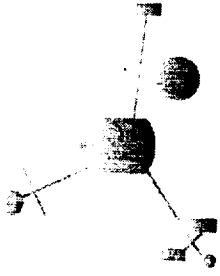
GRS BGO vs NaI

Project Overview

LOCKHEED MARTIN

Lunar Spectrum: 90 lines + continuum



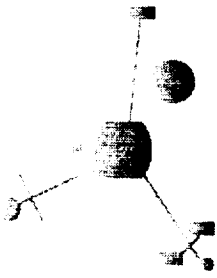


Science Requirements.

■ Project Overview

LOCKHEED MARTIN

- S/C must support payload with following characteristics:
 - Mass: 21 kg
 - Power: 17 w
 - Data rate: 1490 bps
 - Boom mounted
 - 1 year life-time
- GRS
 - boom 2.5 x S/C dimensions
 - S/C radioactive level <0.3 photons/cm²/s above 100 keV
- MAG/ER
 - Time-varying field <0.1 nT at <16 Hz, Steady field <0.5 nT
 - Boom and S/C must be conducting
 - Spin rate at 12.0 ± 0.7 rpm
- DGE
 - Doppler to <1 mm/s avg. over 10 s
 - Antenna's phase center and S/C spin axis should coincide



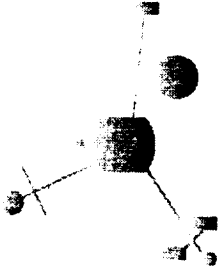
Spacecraft Requirements

■ Project Overview

LOCKHEED MARTIN



- Simple spin stabilized S/C
 - Low cost
 - High reliability
 - Simple operations
- Dry mass <150 kg
- $\Delta V = 1430$ m/s
- Attitude controlled to $\pm 0.5^\circ$
- Hydrazine monopropellant system for ΔV , attitude and spin control
- 1 year lift-time
- Collect, store (during Earth occultation) and transmit data from each orbit
- Survive total umbral lunar eclipses (no longer required)
- S-Band up- and downlink
- Navigation requires Doppler <5 mm/s avg. over 10 s



Spacecraft Design

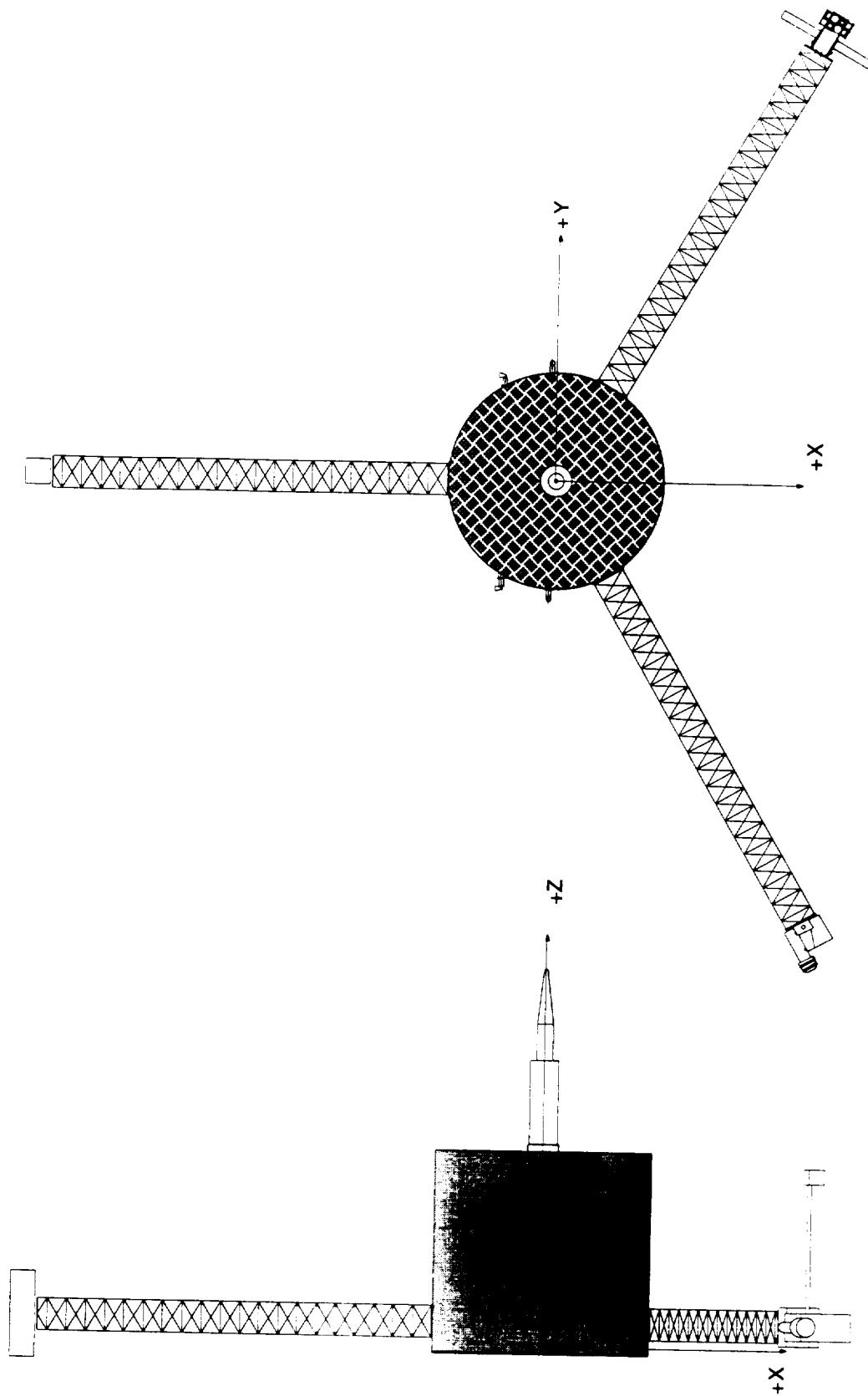


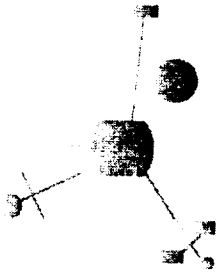
- **Simple, reliable spacecraft with minimum operational requirements**
- 143 kg dry, graphite-epoxy bus with three 2.5 m Able mast booms
- Hydrazine monopropellant propulsion subsystem with six 22 N thrusters provides 1430 m/s ΔV for orbit, spin and attitude control
- S-Band transponder with medium gain and omni antennas support 3.6 kbps down link and Doppler tracking
- Body mounted solar cells provide 206 w and 7 amp-hr battery
- Passive thermal control and heaters
- Spin-stabilized, ground controlled attitude with sun and IR limb sensors
- Ground command and control of S/C via 128 (max.) commands (**no onboard computer**)
- Ground commanded science instruments via serial commands
- Data downlinked in real-time and 53 minute delayed streams to account for Earth occultations

Spacecraft Configuration

■ Project Overview

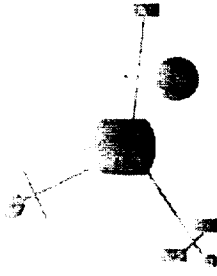
LOCKHEED MARTIN





Mission Requirements

- Launch to near minimum energy translunar trajectory ($C3 \approx -2 \text{ km}^2/\text{s}^2$)
- Translunar cruise
 - Two midcourse maneuvers
 - Boom deployment
 - MAG calibration data in geomagnetic field
 - GRS, NS and ER bake-out for 1 day
 - All instruments collect translunar calibration data
- Lunar Orbit Insertion (LOI)
 - Low thrust LOI burn(s)
 - Collect calibration data in intermediate orbits if possible
- Mapping orbit
 - Polar
 - 100 km altitude
 - 118 minute period
 - Periodic orbit maintenance maneuvers



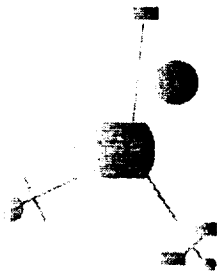
Extended Mission Option

■ Project Overview

LOCKHEED MARTIN



- Spacecraft capabilities (ΔV , etc.) allow 2 year extended mission in nominal mapping orbit
- Nominal mapping for 2 extra years would mainly enhance Al, Ca, Si, Mg and gas release event data sets
- Low altitude mapping would use ΔV reserves rapidly and shorten extended mission to several months
 - 50 km altitude circular orbit mapping would enhance magnetic, gravity, water ice and H distribution data by a factor of >10
 - 10 km periaapsis mapping would enhance the above data sets by a >10,000



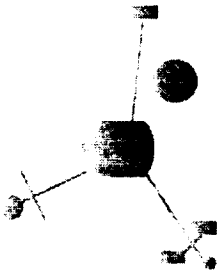
Operational Requirements

■ Project Overview

LOCKHEED MARTIN

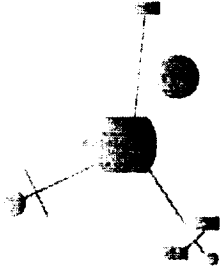


- Tracking
 - Dedicated 24 hour, world-wide tracking network
 - >7 m diameter tracking antennas
 - Terrestrial communication network
- Command and control
 - Dedicated Lunar Prospector Command and Control Center
 - Orbit analysis and prediction
 - Mission planning
 - Data archiving



Operations

- Tracking
 - Wallops-DSN-DSN world-wide tracking network
 - 70 - 90% coverage
 - 8, 26 and 34 m diameter tracking antennas
 - DSN terrestrial communication network
 - Dedicated outreach downlink tracking network may result in 100% coverage
- Command and control
 - Ames/Pioneer Command and Control Center
 - GSFC orbit analysis and prediction
 - Mission planning
 - Data archiving plan completed

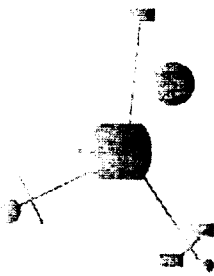


Support, Outreach and Education

Project Overview

LOCKHEED MARTIN

- “Grass roots support”
 - Aerospace States Association
 - National Space Society
 - Members of Congress
 - Space Grant
 - Universities in other countries
- Outreach
 - Museums
 - News media coverage
- Education
 - School kids “Command and Control” program
 - High school teacher team members



Congressional Record

■ Project Overview

LOCKHEED MARTIN



- From Congress on LP and Discovery

The Committee commends NASA for continuing the Discovery program to promote low-cost exploration of the solar system, and endorses the program because it is demonstrating a real commitment to innovative management techniques that lower the cost of space exploration. Furthermore, the Discovery program addresses the problems associated with NASA's recent approach to space exploration, which relied on large, expensive spacecraft in development for a decade or more. Consequently, the Committee recommends **full funding for the Lunar Prospector**, a low-cost science probe to the moon which will build on the Defense Department's successful Clementine mission of 1994 and now has a strong educational component provided separately by the private sector. **Lunar Prospector represents the type of resource-leveraging that NASA must perform in an era of constrained budgets.**

4.0 PROJECT STATUS

A. BINDER

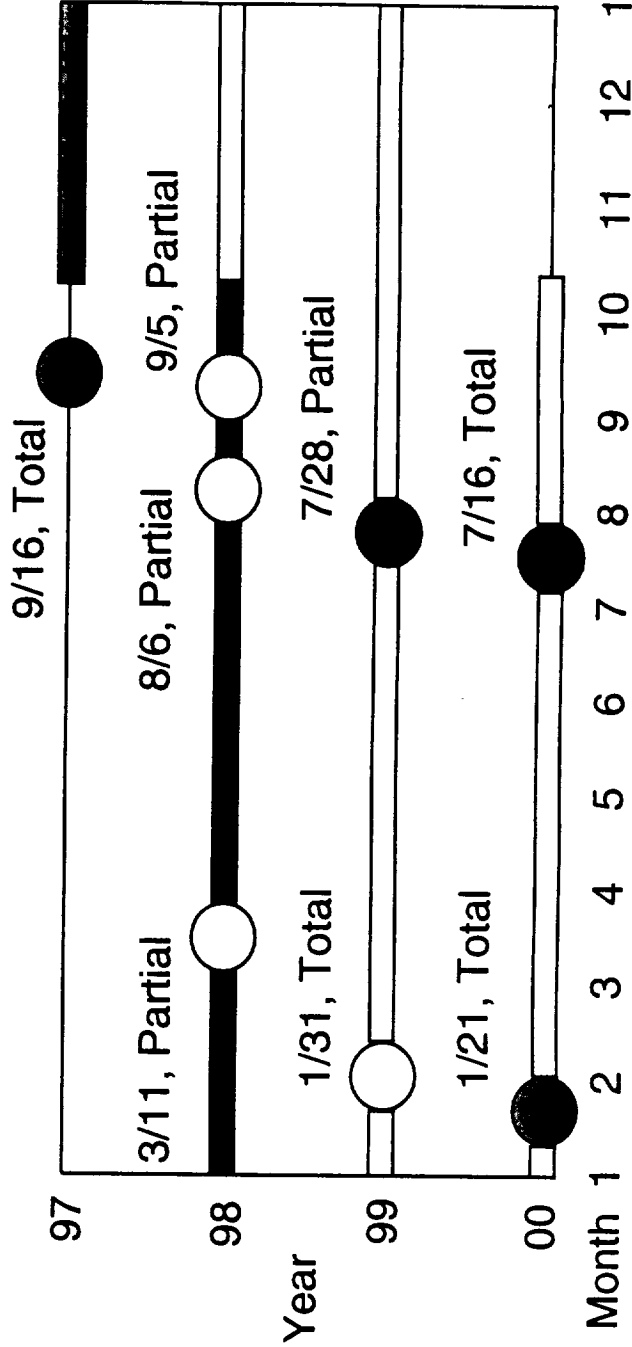
Programmatic Changes

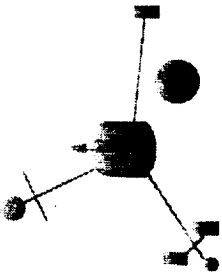
Project Status

LOCKHEED MARTIN

● Launch date

- Proposal: June, 1997
- Current: Oct. 9, 1997
- Reasons: Launch **after** Sept. 16 total umbral ● eclipse
 - only penumbral ○ eclipses during nominal mission ■
 - and even in early extended mission □
 - reduces battery and thermal requirements and mission risk





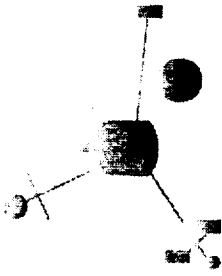
Programmatic Changes (Cont.)

Project Status

LOCKHEED MARTIN



- Tracking network
 - Proposal: Dedicated Allied Signal commercial network of three 6 m stations with essentially 100% coverage
 - Current: Wallops-DSN-DSN network (8, 26 and 34 m antennas) with 70 - 90% coverage $\pm$ outreach downlink stations
 - Reasons: Issues regarding commercial use of NASA frequencies and access to NASA facilities in other countries and reduced cost
- Spacecraft subsystems
 - Proposal: Primary and backup for most units
 - Current: Single string for most units
 - Reasons: Reduces cost, mass and power without unduely increasing risk



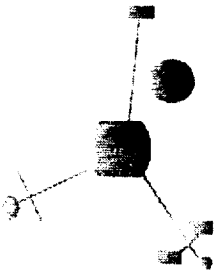
Tracking/Record Trade

Project Status

LOCKHEED MARTIN



- 70 to 90% Wallops-DSN tracking coverage: **No Significant Losses**
 - Satisfies mission goals (see Experiment Duration Chart) except GRS mapping of Al, Ca, Si and Mg, which require extended mission **regardless**
 - Experiment Duration Chart is conservative
 - 2 σ values
 - Calculated for equator
 - Neglects NS and anticioincident supplementary data
 - Dedicated outreach network should result in 100% coverage
 - Requires NO commanding or sequencing to acquire data
 - LP remains simple low risk S/C and mission
- 50 Mb recorder to achieve 100% coverage: **No Significant Gains**
 - Less DSN coverage required
 - \$100k hardware cost plus
 - More complex and costly mission operations, need both “continuous” command capability and sequence planning
 - Increased S/C and mission complexity and risk



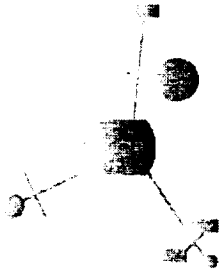
Programmatic Changes (Cont.)

Project Status

LOCKHEED MARTIN



- Spacecraft mass
 - Proposal: 126 kg
 - Current: 143 kg* (13% increase)
 - Reasons: Change in main load bearing structure to reduce cost (see structural changes)



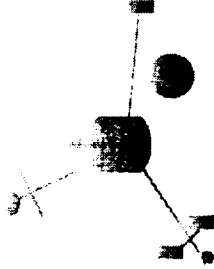
Science Instrument Changes

Project Status

LOCKHEED MARTIN



- GRS operational temperature
 - Proposal: $+10 \pm 5^{\circ}\text{C}$
 - Current: Passive and controlled cooling to $-40 \pm 1^{\circ}\text{C}$
 - Reason: Passively cooling detector to -40° increases its resolution from 11 to 8%, thereby increasing precision of data by a factor of 1.5 to 5 (Note: the thermal shield was changed from a cylinder to a rectangular box to facilitate the addition of reflecting surfaces to the shield to bring the temperature down 50°C)
- GRS boom mounting orientation
 - Proposal: Long axis perpendicular to spin axis
 - Current: Long axis parallel to spin axis
 - Reason: Reduces effects of non-isotropic response function as function of spin phase

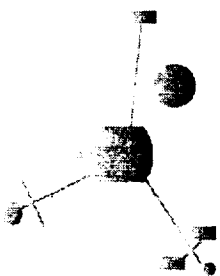


Science Instrument Changes (Cont.)

Project Status

LOCKHEED MARTIN

- NS and APS mounting
 - Proposal: NS and APS 2 separate units, with APS mounted at end of boom, NS mounted 1 m closer to S/C
 - Current: NS and APS in 1 common box mounted at end of boom
 - Reasons: Eliminates need for, and cost and complexity of, boom extension and hinge since Able mast was chosen as the best boom (see structure changes)
- APS detectors
 - Proposal: APS had 33, 2 cm dia. detectors mounted on 11 sides of a pentagonal dodecahedron and 11 sets of electronics
 - Current: APS has 10, 3x3 cm detectors mounted on 5 sides of a cube and 5 sets of electronics
 - Reasons: Simpler and lower cost configuration (3x3 cm detectors were not previously available)

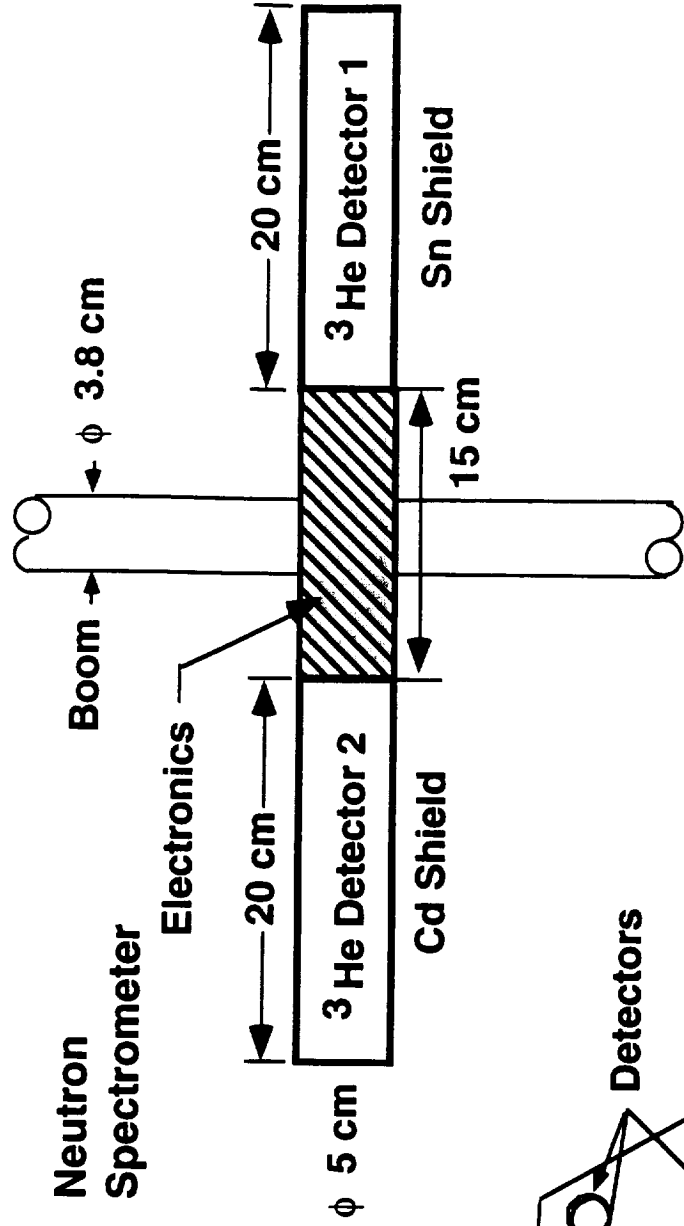


Project Status

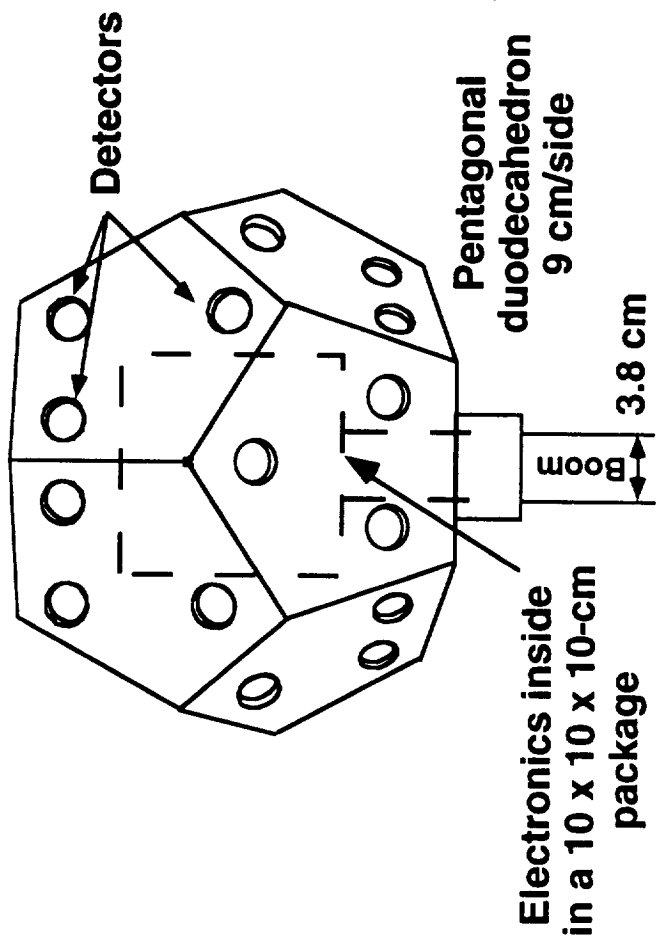
APS and NS

LOCKHEED MARTIN

Neutron Spectrometer



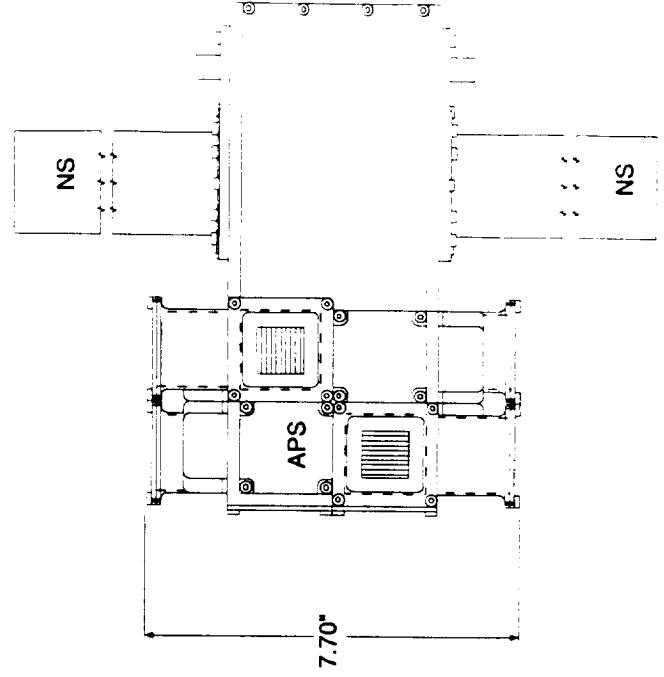
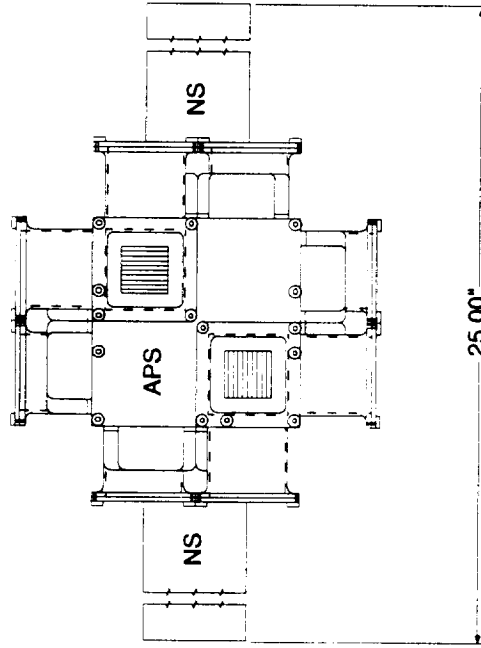
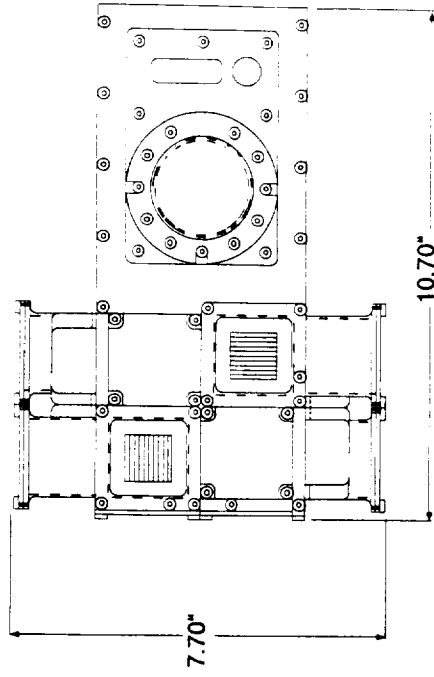
Alpha Particle Spectrometer

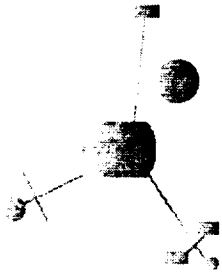


APS and NS Assembly

Project Status

LOCKHEED MARTIN





Science Instrument Changes (Cont.)

Project Status

LOCKHEED MARTIN

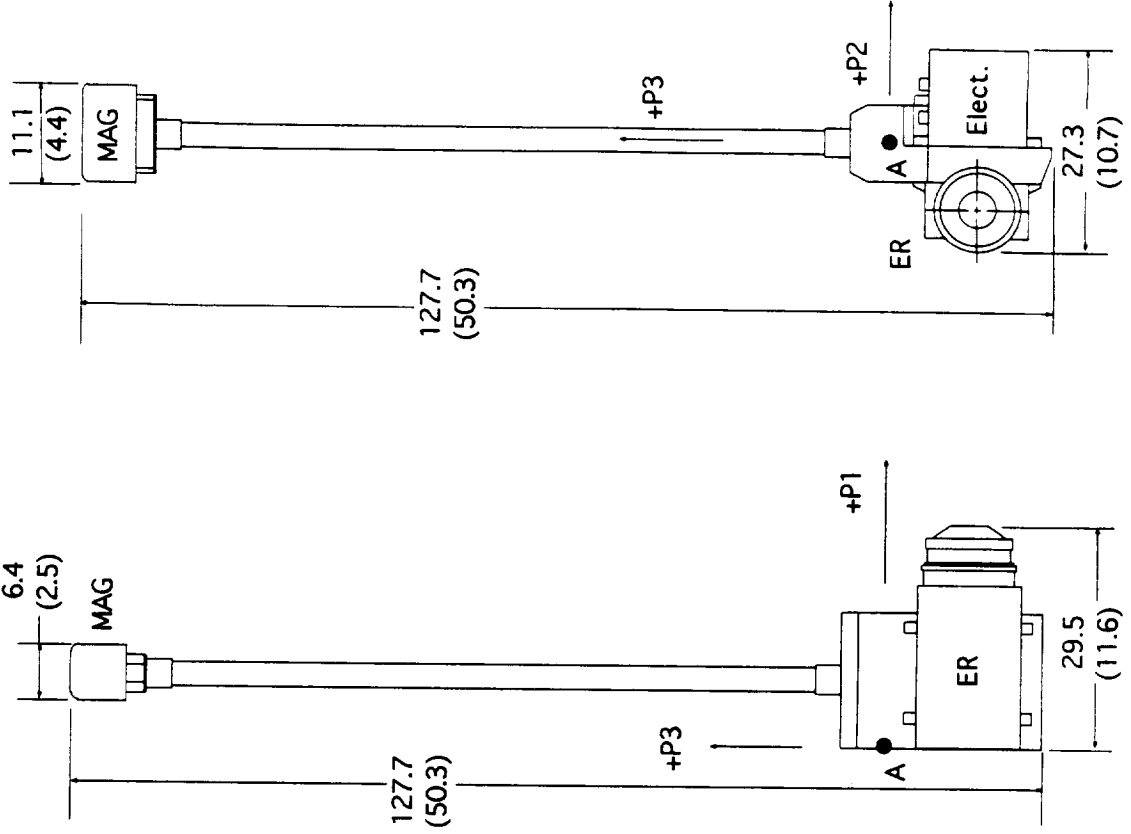


- MAG mounting
 - Proposal: MAG mounted at end of common MAG/ER boom with ER and common electronics mounted 1 m closer to S/C
 - Current: MAG extension is at right angle to main boom with extension in +z direction
 - Reasons:
 - Eliminates need for, and cost and complexity of, hinge since Able mast was chosen as the best boom (see structure changes)
 - Allows MAG and boom extension to be secured during launch

MAG/ER

LOCKHEED MARTIN

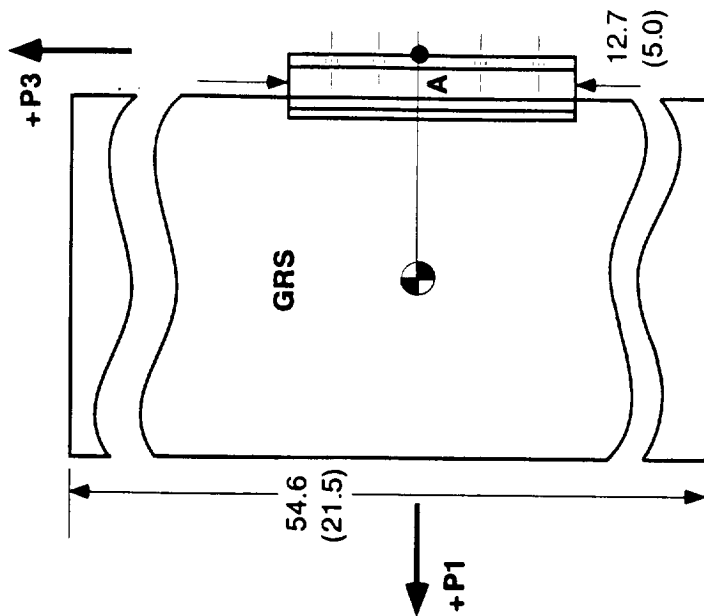
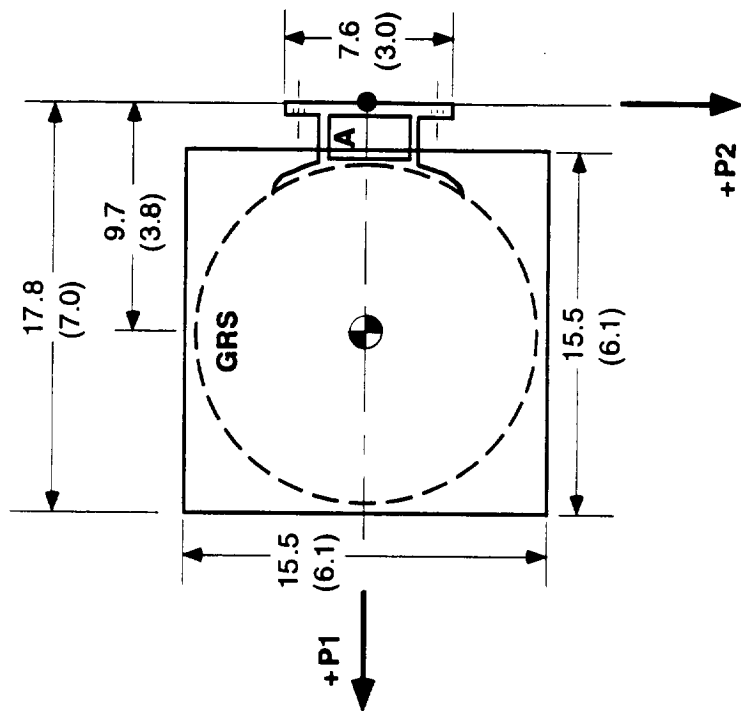
Project Status

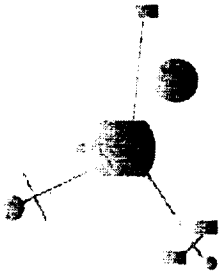


GRS

Project Status

LOCKHEED MARTIN





Structure Subsystem Changes

Project Status

LOCKHEED MARTIN



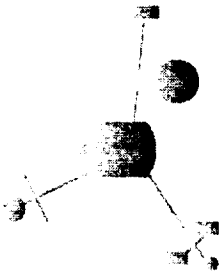
- Boom structure
 - Proposal: Hinged graphite-epoxy segments
 - Current: Able mast
 - Reasons: Superior deployment dynamics increases mission reliability and reduced costs
- Boom length
 - Proposal: 3.5 m
 - Current: 2.5 m
 - Reasons:
 - Reduced mass
 - Increased stability of spacecraft's cg
 - Reduced cost
 - Insignificant impact on science data

Structure Subsystem Changes (Cont.)

Project Status

LOCKHEED MARTIN

- Load bearing structure
 - Proposal: Launch adapter, equipment shelf and tank **cone**
 - Current: **Triangular structure** and equipment shelf
 - Reasons:
 - Reduced cost, replication or use of existing triangular structure
 - 3 low cost separation nuts attach directly to simple TLI stage adapter vs more expensive launch adapter and Marmon clamp
- Inverted structure
 - Proposal: S/C equipment mounted on bottom of equipment shelf at bottom of S/C, (post-proposal) booms at top of S/C
 - Current: S/C equipment mounted on top of equipment shelf at top of S/C, booms at bottom of S/C,
 - Reasons: Better access to subsystem units and cg control (see next bullet)



Structure Subsystem Changes (Cont.)

Project Status

LOCKHEED MARTIN



- Center of Gravity in Z direction
 - Proposal: Not addressed (remnant of OMNI design)
 - Current: Plane through the centers of propellant tanks and the 2 tangential thrusters contains the cg
 - Reasons: cg **must** remain constant as propellant is depleted and tangential thrusters **must** fire in the cg plane defined above **or** the spacecraft will slowly change attitude during “vector burns”; this requires that the science instruments/booms and S/C equipment be at opposite ends of S/C to balance S/C
- Boom release mechanism
 - Proposal: Pyro bolt cutters
 - Current: Paraffin actuators
 - Reasons: Better shock environment and reduced cost

Thermal Subsystem Changes

Project Status

LOCKHEED MARTIN



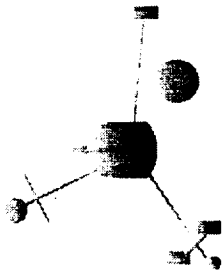
- Radiator
 - Proposal: FOSR ring around equipment bay
 - Current: Top of spacecraft is radiator surface
 - Reasons: Proximity of equipment bay to top of spacecraft eliminated need for FOSR ring, leaving more area for solar array

Power Subsystem Changes

Project Status

LOCKHEED MARTIN

- Power control unit
 - Proposal: Separate bus voltage limiter and battery control units of OMNI conceptual design
 - Current: All functions in single unit using previously flown Lockheed design
 - Reasons: Lower cost and risk using flight proven design
- Voltage regulator
 - Proposal: Separate voltage regulator for spectrometers
 - Current: Voltage regulator built into spectrometer electronics
 - Reasons: Simplified interfaces between power subsystem and spectrometers

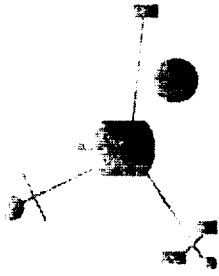


Power Subsystem Changes (Cont.)

Project Status

LOCKHEED MARTIN

- Battery capacity
 - Proposal: 15 amp-hr
 - Current: 7 amp-hr
 - Reasons: Change in launch date, no need to survive total eclipses during nominal mission (see programmatic changes)
- Battery type
 - Proposal: Nickel-hydrogen
 - Current: Nickel-cadmium
 - Reasons:
 - Better thermal characteristics, eliminated need for special radiator and reduces thermal power requirements
 - Availability of flight proven battery with required capacity



Communication Subsystem Changes

■ *Project Status*

LOCKHEED MARTIN 

- S-Band Transponder
 - Proposal: Motorola transponder
 - Current: Loral Clementine transponder
 - Reason: Very large cost savings using flight proven transponder
- Medium gain antenna
 - Proposal: Slotted phased array (OMNI concept)
 - Current: Helix antenna
 - Reasons: No vendor of slotted phased array antenna found, Lockheed has built an X-Band Helix antenna, the design of which can be modified for S-Band

Propulsion Subsystem Changes

Project Status

LOCKHEED MARTIN



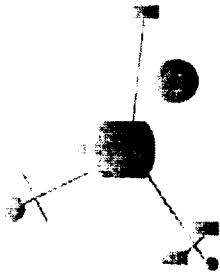
- Tank configuration
 - Proposal: 4 tanks
 - Current: 3 tanks
 - Reasons:
 - Lower cost, mass and complexity (fewer lines, welds, etc.)
 - Compatible with triangular load bearing structure (see structure changes)
- ΔV budget
 - Proposal: 1330 m/s
 - Current: 1430 m/s
 - Reason: 100 m/s increase to midcourse maneuver budget to account for 3 σ injection errors of TLI stage

Propulsion Subsystem Changes (cont.)

Project Status

LOCKHEED MARTIN

- Latch valve and cavitating venturi
 - Proposal: Latch valve and cavitating venturi in baseline
 - Current: No latch valve and cavitating venturi
 - Reason: Components not needed for launch preparation safety since propellant mass is small
- Thruster type
 - Proposal: Straight nozzle thrusters
 - Current: Right angle nozzle thruster
 - Reasons:
 - Avoids valve failure due to dislodged catalysts fines in the upper, vertically aligned thrusters as a result of launch vibrations
 - Allows valve assembly of tangential thrusters to be inside spacecraft to reduce heater power usage (keeps propellant from freezing)



C&DH Subsystem Changes

Project Status

LOCKHEED MARTIN



- C&DH configuration
 - Proposal: Separate Command Control, data processing, squib driver and valve driver units using OMNI conceptual designs
 - Current: Single unit
 - Reasons: Lower costs, mass and power usage

5.0 MANAGEMENT

T. DOUGHERTY

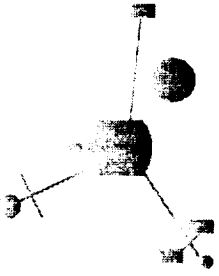
Management

■ Program Management

LOCKHEED MARTIN



- Implementation
- Acquisition
- Decision process
- Configuration management
- Subcontracts
- Manufacturing
- Schedule
- Earned value



Program Implementation

■ *Program Management*

LOCKHEED MARTIN



- Phase B nearing completion
- Program system configuration defined for Instruments, spacecraft, mission controls and tracking
- Launch system selection 12/15/95
- Organization established with assigned functions and responsibilities
- Baseline schedule and budget in place to afford earned value assessment
- Program controls defined for configuration control, visibility and resource management
- Spacecraft configuration baselined: systems specification, subsystem specification, Instrument and ground station Interface Control Drawings, and spacecraft assembly and program hardware/software testing

Program Implementation

(Cont'd)

■Program Management

LOCKHEED MARTIN

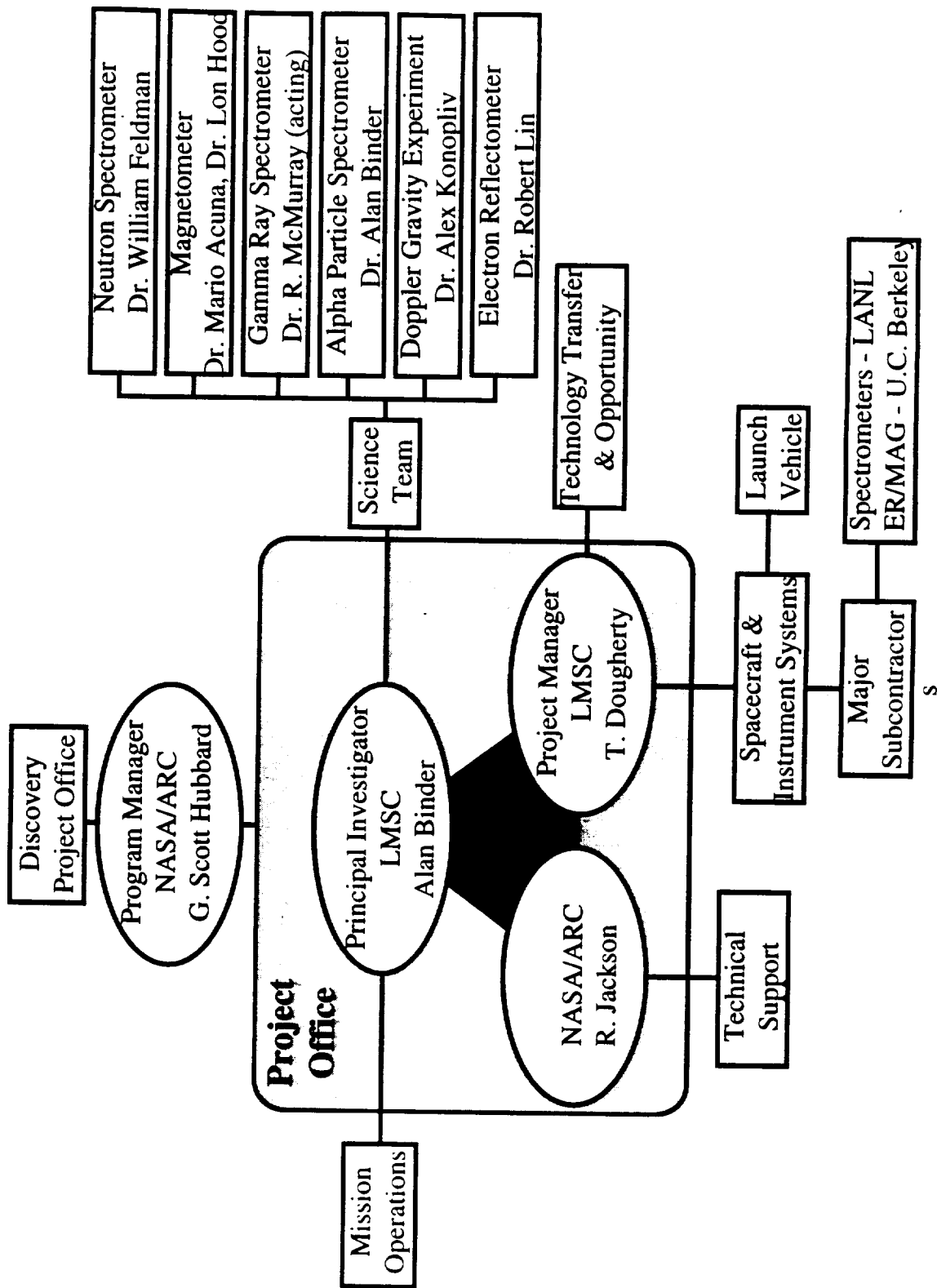


- Documentation for procurement and fabrication to be complete on 9/29/95.
- Attitude control consultants obtained from Astro division.
- Software development to be supported by GPB software facility.
- Ground system configuration includes Ames mission & control center and TOTS/DSN tracking system.
- Risks identified, mitigation plans and metrics being prepared.
- SRM & QA manager assigned to program.
- Strong tie programatically/technically with GPB Skunk Works Operation.



■ Program Management

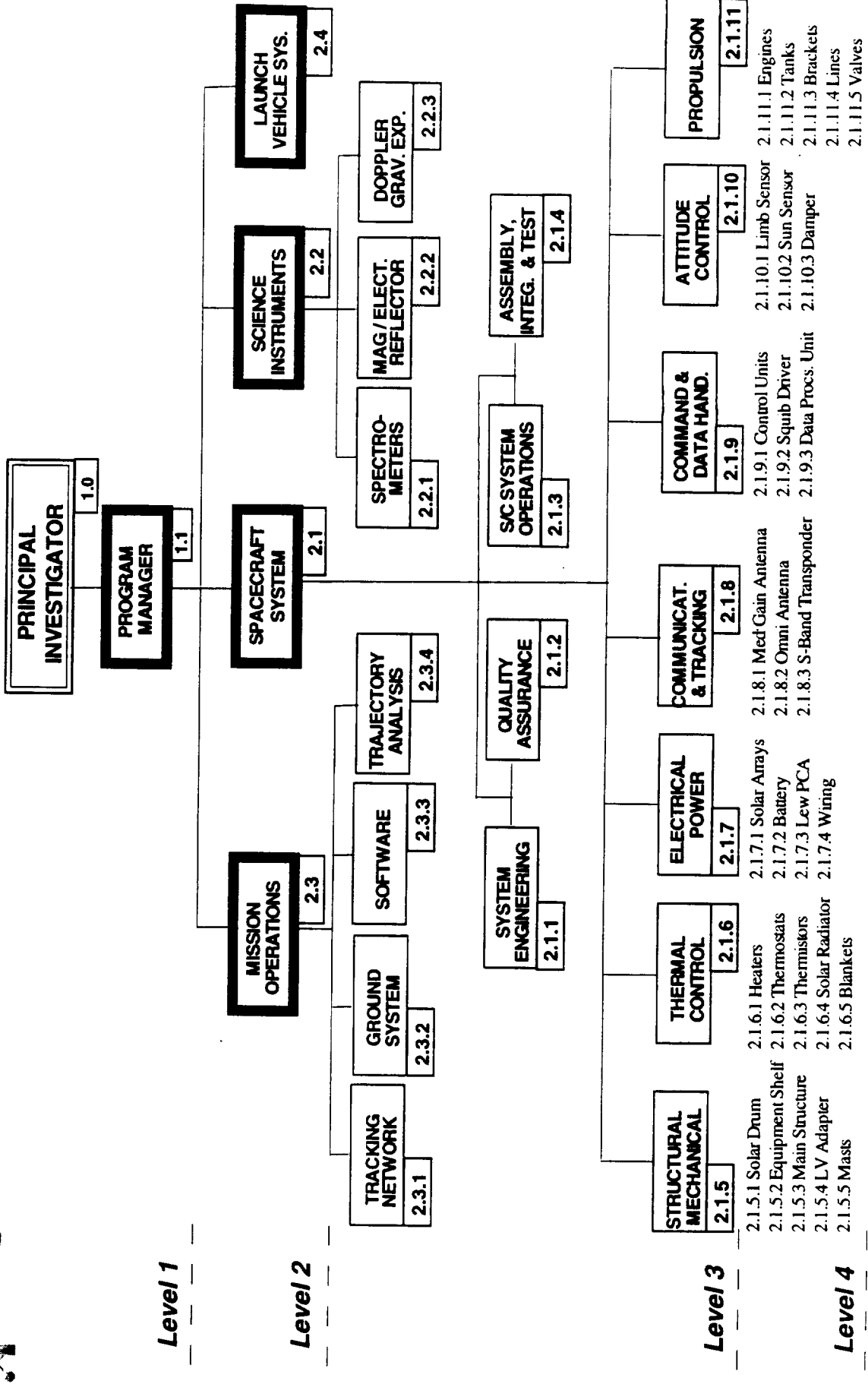
LOCKHEED MARTIN



Work Breakdown Structure

LOCKHEED MARTIN

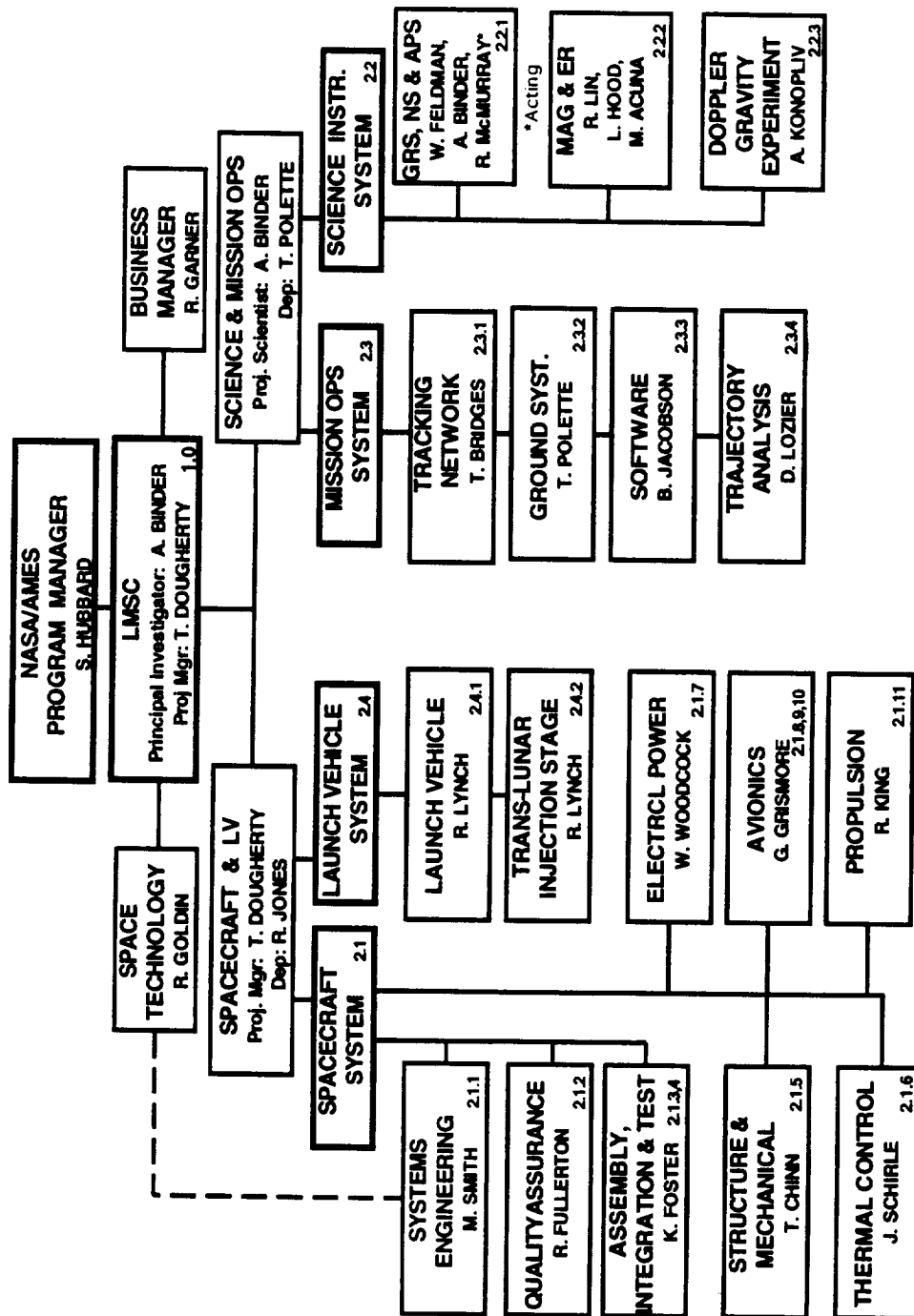
Program Management

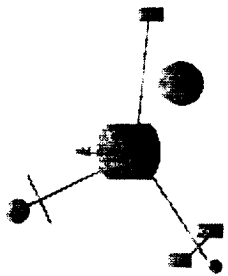


Organization Chart

Program Management

LOCKHEED MARTIN

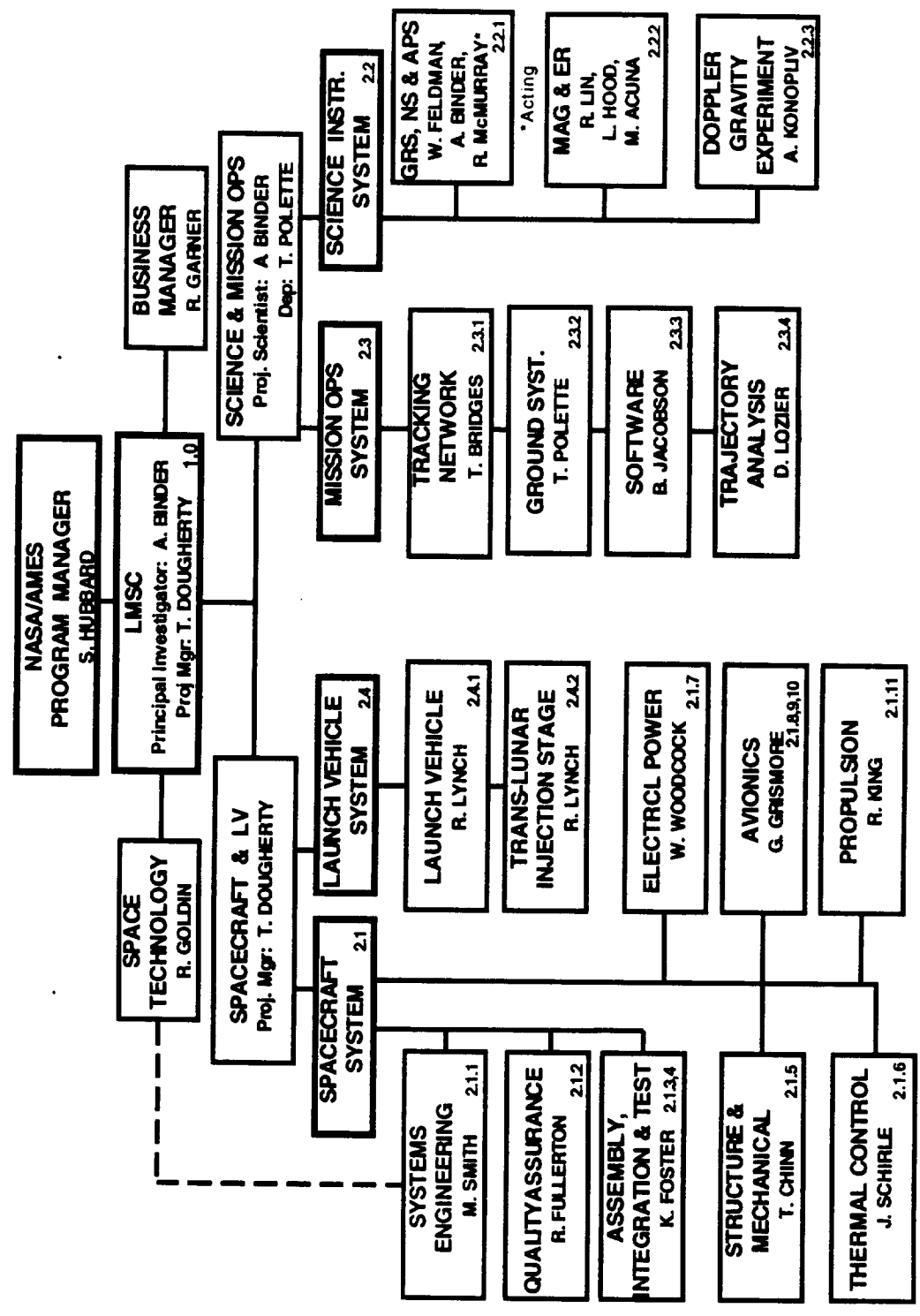




Organization Chart

LOCKHEED MARTIN

Program Management



Resumes

■ *Program Management*

LOCKHEED MARTIN

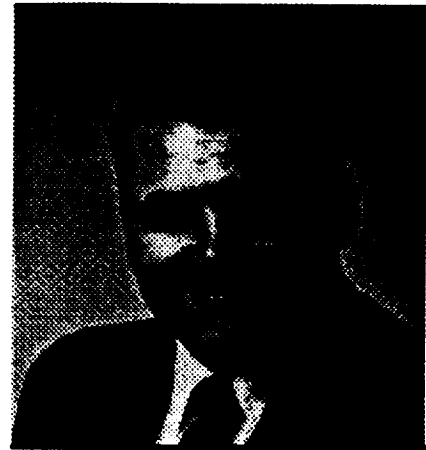


Thomas A. Dougherty

Position - Project Manager of Lunar Prospector Program

Education

- MBA, San Jose State University, 1967
- MS Electrical Engineering, San Jose State University, 1964
- BEE, City College of New York, 1961



Other Experience

- Earth Observing System, Deputy Program Director, 1994-95
- Relativity Mission, Deputy Program Manager, 1994
- Hubble Space Telescope, First Servicing Mission Program Manager, 1990-94.
- Hubble Space Telescope, Assistant Program Manager responsible for subcontracts, government furnished equipment, manufacturing and program controls, 1977-1989.
- Subcontract Program Manager for attitude control hardware for large Lockheed proprietary spacecraft study, 1969-1976.
- Systems integration, subsystem engineering, hardware engineering, 1961-1968.

Honors

- NASA Distinguished Public Service Medal for outstanding management and technical leadership on the first Hubble Space Telescope Servicing Mission, 1994
- NASA Public Service Medal for exceptional technical and management contributions to the Hubble Space Telescope, 1991

Robert W. Goldin

Position - Space Technology Project Engineer for Lunar Prospector

Education

- MSCE, California Institute of Technology
- BSCE, University of Pennsylvania

Other Experience

- Consulting Engineer on LMSC Advance Program Studies, including SOFIA, MGS, SIRTf, LRM, and EOS, 1990-1994
- Space Technology Project Engineer on two major programs: the NASA/JPL Seasat Program, from 1976 through 1979, and the Hubble Space Telescope, from 1980 through 1990. Responsibilities on both programs were to coordinate and direct the spacecraft design and analysis tasks carried out by the primary space technology disciplines including structural dynamics, vibro-acoustics, loads analysis, stress analysis, mass properties and thermal analyses.
- Manager and Consulting Engineer for advance system studies on the Polaris/Poseidon weapon system, the Agena upper stage/spacecraft, and the Space Shuttle. On the Space Shuttle was responsible for studies related to the thermal protection system and the recoverable solid rocket booster stage, the results from which are incorporated on the operational shuttle vehicle.
- Employed at Bell Aerosystems Company from 1950 through 1960, advancing from assignments as Structural Loads Group Engineer through Assistant Chief Engineer. During that time was a responsible member of the design/analysis teams on the X-1A, X-2, X-5, and X-14 research aircraft.

RALP P. FULLERTON

Position - SRM & QA Representative, NASA & Federal Systems, Lockheed Martin

Experience:

- 1994 to present, Lockheed Martin Missiles & Space; NASA and Federal Systems SRM&QA**
- Directed SRM&QA activities for the ISS FGB Program developing and implementing a Quality Plan, establishing customer and International subcontractor interfaces
 - Monitored the SRM&QA activities on the Hubble FSS, ISS PG-1, ISS PG-2, ISS PG-3 and Gravity Probe B contracts.
- 1992 to 1994, Lockheed Missiles & Space Company; PAPMR, ISS PG-2**
- Responsible for all Product Assurance activity on the Solar Array including delivery of MIR Modules to RSC Energia
 - Successful completion of CDR and the first subcontractor visits to Russian suppliers.
 - Implemented the quality program that successfully delivered the Mir solar array modules to RSC ENERGIA PG-04.
- 1989 to 1992, Lockheed Missiles & Space Company; Manager, Electronics Inspection**
- Managed activities of 60 employees providing Quality Engineering and Inspection for electronics hardware manufactured by SSD.
- 1985 to 1989, Lockheed Missiles & Space Company; Group Engineer, Quality Engineering**
- Directed activities of 30 engineers providing Quality Engineering and Material Review services in both electronics and structures manufacturing.
- 1982 to 1985, Lockheed Austin Division; Group Engineer, Quality Engineering and Inspection**
- Established Quality organization at Lockheed's new Division in Austin, developing operating procedures, staffing the organization, and directing the activities of the quality organization.
- 1975 to 1985, Lockheed Missiles & Space Co.; PAPMR, Various Programs**
- Directed hardware and software activities on SPARCS, PR 212, Navy Tactical Data Systems, and Centaur Shroud Programs including establishing software procedures and hardware systems to accommodate the various customer requirements.

Honors

Pursuit of Excellence, Team of the Month, Developed and Implemented a new concept for inspections role in the total life cycle of SSD Products. PIP Award, Instrumental in the successful completion of the ISS Safety Reliability and Quality Assurance Audit. Numerous Commendations for superior performance.

Kim A. Foster

Position: Assembly, Integration, & Test Manager of Lunar Prospector Program

Education:

- MS Engineering Management, University of Santa Clara, 1990
- BS Electrical Engineering, Oregon State University, 1980

Other Experience:

- IRIDIUM® Commercial Program, Assembly, Integration & Test Staff Engineer, 1994-95
- NASA Programs New Business, Science Instrument Accommodation and Integration & Test Staff Engineer, 1993-94
- IRIDIUM® Commercial Program, Systems Engineering Staff Engineer, 1991-93
- Hubble Space Telescope, Assembly, & Verification Group Engineer, 1987-91
- MILSTAR USAF Program, Payload Systems Test Group Engineer, 1986-87
- Hubble Space Telescope, Science Instruments Assembly & Verification Group Lead, 1980-86
- Stevenson Engineering & Manufacturing Co, Control Systems Responsible Engineer, 1979-80

Honors:

- Productivity Improvement Program Superior performance award and NASA & Federal Systems Team of the Month, MUADEE & LP Proposals work, 1994
- Productivity Improvement Program awards, NASA Proposals, 1993, 1994, and 1995
- Selected for the following Lockheed leadership and training programs and completed associated courses and assignments: Systems Engineering Training (SET) Program, Lockheed Exceptional Achiever Development (LEAD) Program, Lockheed Supervisory Institute (LSI), and Supervisory Training & Educational Program (STEP), 1988-92
- IRIDIUM® Commercial Program Special Award, Systems Engineering, 1991
- Hubble Space Telescope Performance Award, Launch & Mission Operations Support Team, 1990

Thomas Chinn

Position - Lead Designer of Lunar Prospector Program

Education

- MS Civil Engineering, University of Washington, 1961
- BS Civil Engineering, Seattle University, 1958

Other Experience

- SSD Center of Excellence, Composite Design Engineer, 1995.
- Earth Observing System, Composite engineer responsible for the design and manufacturing of a composite optical bench for development and testing, 1992-95.
- Manufacturing Project leader responsible for the development of a one-piece co-cured modular composite structure for spacecraft application, 1988-92.
- Manufacturing Engineer, Assist in the research and development of composite components for engineering application, 1985-1988
- MSD System Engineering, Responsible for composite hardware on the C4 Fleet Ballistic Missiles, 1980-88.
- MSD Stress Analyst, Perform stress analysis on the FBM program, 1966-1980.

Honors

- LMSC Productivity Program President's Award, for Outstanding Achievement in Productivity Innovation Benefitting LMSC, 1991.
- Winner of 4th quarter Pursuit of Excellence Award, 1990.

James R. Schirle

Position - Lead Thermal Engineer for Lunar Prospector

Education

- MSME, Santa Clara University, 1985
- BSME, San Jose State University, 1979

Other Experience

- Group Engineer, Satellite Engineering - Responsible for spacecraft thermal design integration, analysis, and testing for the Iridium® Bus Program. Additional responsibilities include supervision and technical support for LMMS's Commercial Remote Sensing Program and Spacecraft Center of Excellence. 1992-1995.
- Group Engineer, Spacecraft Thermodynamics - Responsible for thermal design, analysis, and test support for a spin stabilized spacecraft. 1988-1992.
- Research Specialist, Spacecraft Thermodynamics - Supported new business and proposal activities. 1987-1988.
- Thermodynamics Engineer, Lead thermal engineer on P397 program - Provided thermal design and analysis support from concept definition through CDR. 1983-1987
- Thermal Engineer - Provided thermal design, analysis, and test support for numerous LEO and GEO spacecraft. 1979-1987.

William (Woody) Woodcock

Position - Electrical Power Lead Engineer

Education

- B. S. Physics, Ohio University
- M. S. Physics, Ohio University

Other Experience

- More than twenty years' experience in the design, development and analysis of various EPA components, including solar cells, panels, and deployable wings, harnesses, cable-wraps, slip rings, power electronics, stepper and DC torque motors and gearing systems, encoders, drive electronics and sun sensors.
- Fifteen years' technical responsibility with subcontracts for high-value EPS hardware components.
- Five years' experience as EPS Lead Engineer supporting electronics hardware fab, assembly, installation, and check-out and performing EPS subsystem performance analysis in support of spacecraft-level test and post-delivery operations.

Honors

- Co-author of two published papers on Solar Array Technology.

Gerald A. (Gerry) Grismore

Position - Avionics Subsystem Lead Engineer

Education

- MS Engineering, University of Santa Clara, 1971
- BS Electrical Engineering, U.C. Berkeley, 1961

Other Experience

30 + Years - Lockheed Missiles & Space Co.

- 1992-1994 Command and Data Handling Engineer (EOS Phase B Study Program)
- 1988-1992 Command and Control Systems Engineer (Multiple Classified Programs)
- 1981-1988 Systems Requirements Engineer (Image Data Exploitation Systems)
- 1976-1981 Hardware/Software Integration Lead (Major Classified Program)
- 1971-1976 Hardware/Software Test Engineer (Ascent Agena Program)
- 1966-1971 Attitude Control System Engineer (Agena Satellite Programs)
- 1963-1966 System Test and Launch System Engineer (Agena Satellite Programs)

Ronald W. King

Position - Propulsion Engineer for Lunar Prospector

Education

- M. S. Aeronautics & Astronautics, Massachusetts Institute of Technology
- B. S. Engineering Science, Pennsylvania State University

Other Experience

- Twenty-eight years of experience in analysis, design, development, and testing of propulsion systems and components.
- Staff engineer responsible for development of advanced technology for spacecraft propulsion systems.
- Program lead for design and low gravity demonstration of a cryogenic propellant tanks.
- Lead on analysis effort to redesign Eirpstar propellant management device component that failed during qualification testing.
- Developed thrust measurement stand for characterization testing of MILSTAR 5 lb thrusters.
- Program lead for development of thrusters to utilize helium boil off from space based cryostats.
- Lead for design of ACRV propulsion subsystem.

Honors

- Member of AIAA Liquid Propulsion Technical Committee
- Licensed Professional Engineer, Mechanical Engineering, State of California

Richard Jay Lynch

Education

Purdue University; West Lafayette, Indiana

Bachelor of Science in Aeronautical and Astronautical Engineering, May 1990

Other Experience

- Launch System Integration
 - Created a data base system to track requirements and the associated evidence of completion
 - Analyzed the evidence of completion for each requirement and briefed current status to customer
 - Developed an Interface Requirements Document for the Earth Observing System
 - Participated in software design reviews and system operation tests
 - Interfaced with customers and suppliers to resolve integration action items
 - Tracked and verified Launch System performance
- Lead interplanetary trajectory design team
 - Presented the team's trajectory design to the customer
 - Lead work on an ID project to develop new interplanetary trajectory analysis software
- Developed the application CENTAUR PREDICT for the Macintosh
 - Coordinated with General Dynamics the development of an algorithm to approximate the Centaur coast guidance calculation of the Centaur third burn time and duration
 - Created an algorithm that calculates spacecraft attitude at separation from telemetry data
 - Developed a Graphical User Interface (GUI)

HONORS

Superior Performance Award

Productivity Improvement Program Express Awards

American Institute of Aeronautics and Astronautics

Thomas L. (Tim) Bridges

Position - LMMS Responsible Engineer for Lunar Prospector Ground System

Education

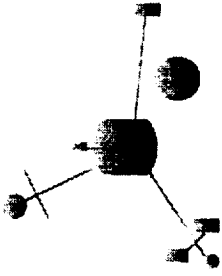
- BSEE, BS Math, 22 credits Post-grad toward MSEE

Other Experience

- 16 years at NASA ARC on Pioneer Project
Responsible for Mission Operations and Ground Data Systems
- ASFOD on Pioneers 6, 7, & 8 and SFOD on 9 & E (bad 2nd stage)
- Ground Data System Manager for Pioneers 10, 11, 12, & 13 (Jupiter & Venus), and for the ARC portion of IRAS.
- Over 10 years at LMSC: Responsible for computers and data systems on HST and classified programs.

Honors

NASA Exceptional Service Medal for outstanding leadership and contributions to the planning, designing, development, and testing of the Ground Data System used successfully in the tracking, data acquisition, and command for the Pioneer Venus Multiprobe and Orbiters Missions; also received numerous Group Achievement Awards and SSPs.



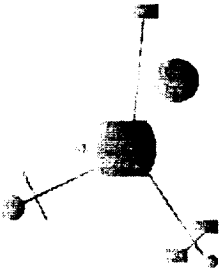
■ Acquisition

Acquisition

LOCKHEED MARTIN



- Science instrument accommodation:
 - Interface Control Document
 - Memo of agreement
 - Budget
 - Schedule
 - Specification
 - Technical support
- Roles and responsibilities
 - Organization
 - Work breakdown structure
 - Cost account managers



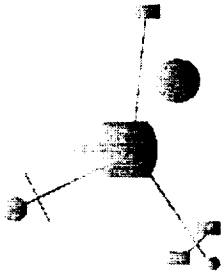
Acquisition (cont'd)

■ Acquisition

LOCKHEED MARTIN



- System, data and service acquisition
 - Mission defined
 - LMMS assembly, integration and test facilities available
 - LMMS launch services agreement ready for approval
 - Ames mission control/archiving
 - NASA TOTS/DSN tracking



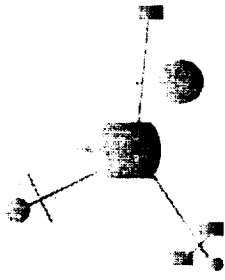
■ Acquisition

Acquisition (cont'd)

LOCKHEED MARTIN



- Procurement and subcontract management
 - Program hardware and software requirements defined and under configuration control.
 - C&DH hardware design RFP released.
 - TLI subcontract in preparation.
 - Procurement documentation in preparation (statements of work, specification and/or drawings) for remaining hardware.
 - Hardware to be procured on fixed price basis.
 - In-house modification in preparation.
 - Long-lead items identified. Adequate schedule relief established.
 - Launch services obtained though launch services agreement.
 - Procurement/subcontract management/administration in place



Acquisition (cont'd)

■ Acquisition

LOCKHEED MARTIN

- Schedule
 - Program schedule included
 - Subsystem schedule included
 - Significant milestone definition to be accomplished near term
- Budget
 - Labor, material, subcontract budget included
 - \$1.8M held in reserve
 - Additional reserve may be obtained from subcontract negotiations, science contribution, labor holdback and launch system selection.
 - Project to be operated as fixed price contract

Acquisition (cont'd)

■ Acquisition

LOCKHEED MARTIN

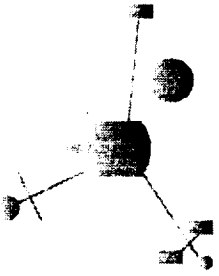


- Personnel
 - \$300K added to phase B to reach procurement maturity
 - Substantial personnel increase to initiate procurement planned for October
 - Impact may result from continuing resolution

Decision process

LOCKHEED MARTIN

- Principal investigator is ultimate authority
- Parallel interaction resolved at next level
- WBS ownership by cost account manager (CAM)



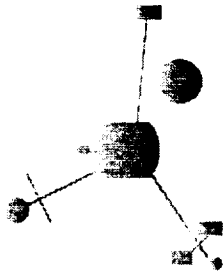
Configuration Management

■ *Program Management*

LOCKHEED MARTIN



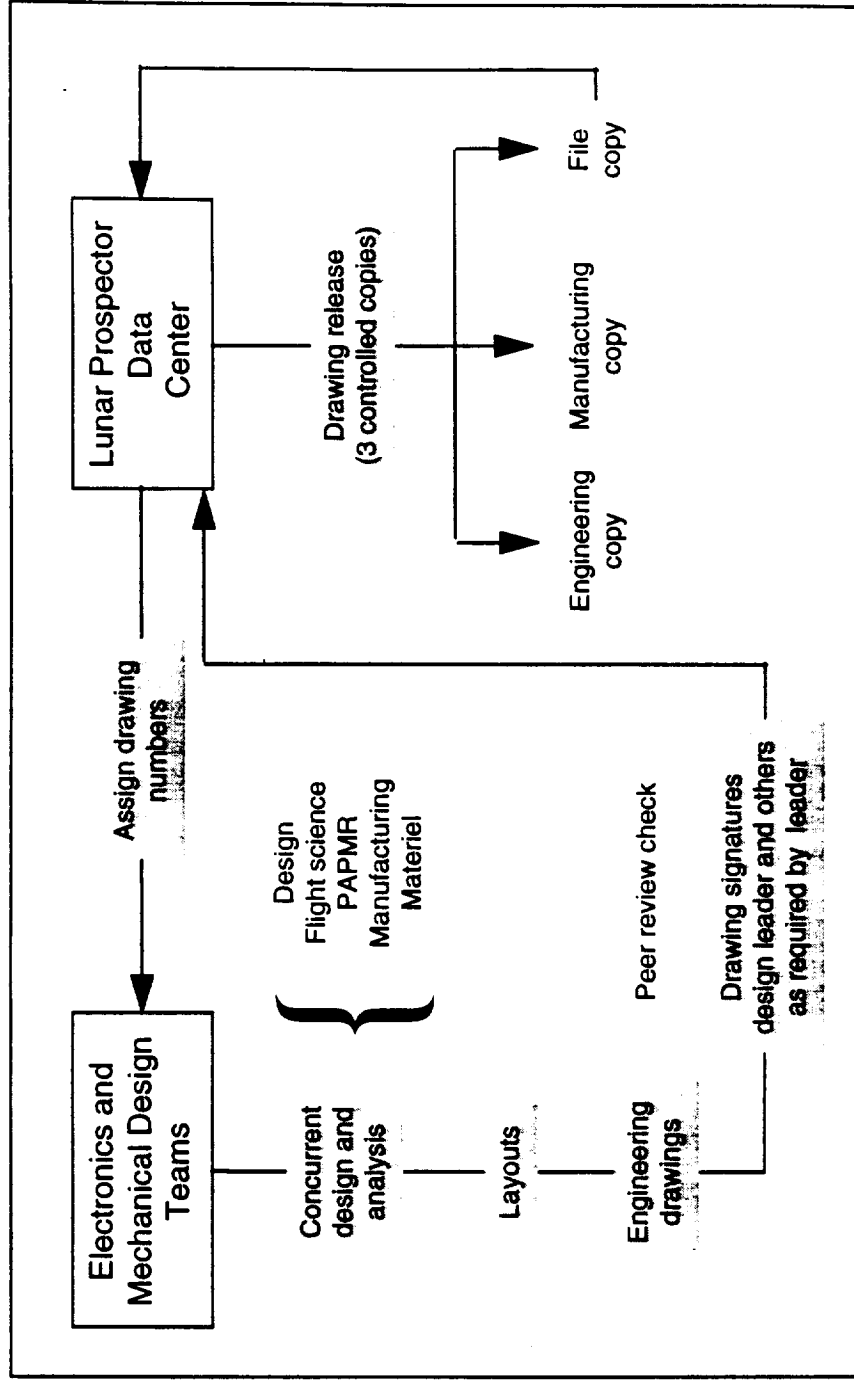
- Baseline spacecraft and instrument interfaces defined.
- All changes to instruments must be approved by Principal Investigator (PI).
- All changes effecting design, cost, schedule of the spacecraft and/or the instrument interface must be approved by the project manager/principal investigator
- Configuration change board includes PI, PM, and System Engineering.

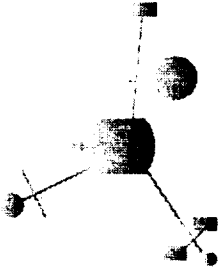


Lunar Prospector Drawing Release System

Program Management

LOCKHEED MARTIN





Subcontracts/Procurement

■ *Program Management*

LOCKHEED MARTIN



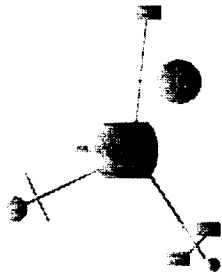
- Subcontract management is responsibility of the cost account manager and subcontract administrator
- Instrument management is responsibility of PI with support for subcontract administrator and spacecraft expertise
- Subcontracts/instruments are fixed price
- Subcontracts/instruments will have performance measurement accountability
- IWT for launch vehicle managed as subcontract

Propulsion PHSL

LOCKHEED MARTIN

Program Management

PROGRAM HARDWARE/SOFTWARE LIST (HARDWARE)			TITLE: Propulsion Subsystem			Ron King -61024			STATUS			CATEGORY			DATE: 28-Aug-95 REVISION: A PAGE: 1 of 1		
PROGRAM HARDWARE/SOFTWARE LIST (HARDWARE)			TITLE: Propulsion Subsystem			PROGRAM OFFICE APPROVAL:			STATUS			CATEGORY			DATE: 28-Aug-95 REVISION: A PAGE: 1 of 1		
ITEM #	WBS #	NOMENCLATURE	DRAWING NO. /	SPEC NO.	STATUS		MAKE / BUY	QUANTITY PER CONTRACT				SEC	REMARKS				
					DESIGN	HDW		D	Q	R	F			S	TOT	CLASS	
2.1.11.1		Engines	MR-106E		E	N	S				6		6		Olin; T=22 N	Psi Brunswick MOOG Psi-Tronics LMMS; similar to Iridium® (75%) LMMS; s.s; sim. to Indium® (75%) 151 kg. 1 kg.	
2.1.11.2		Tanks	80182-1		E	N	S				3		3				
2.1.11.3		Filter	15267-642-2		E	N	B				1		1				
2.1.11.4		Fill/Drain Valve	50E740		E	N	B				2		2				
2.1.11.5		Pressure Transducer	631314-10		E	N	B				1		1				
2.1.11.6		Brackets/Fittings	IST12500		N	N	M				-		-				
2.1.11.7		Lines	IST12500		N	N	M										
2.1.11.8		Hydrazine	MIL-P-26536		E	N	B										
2.1.11.9		He Pressurant	MIL-P-27407		E	N	B										



Subcontractors

Program Management

LOCKHEED MARTIN

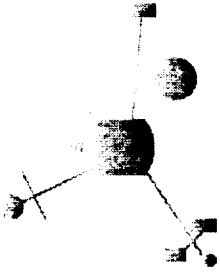


- Thiokol
- Dow
- Southwest/

New Mexico State/Spectrum

- Loral
- Barnes
- PSI
- Olin
- Moog
- Able
- Asec
- Adcole
- Sun

- Kick stage
- Structure
- C&DH
- Transponder
- Limb sensing
- Tanks
- Thrusters
- Valves
- Booms
- Solar cells
- Sun sensor Stimulus
- Terminals



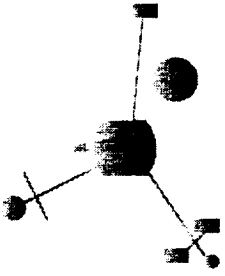
Manufacturing

■ *Program Management*

LOCKHEED MARTIN



- LMMS manufacturing
 - Solar array assembly (TBR)
 - Structure
 - Antenna
- Effort directed by cost account manager through job package authorization (JPA) which defines fabrication task, testing and QA requirements.
- Effort implemented with shop order which is stamped by inspection at successful conclusion.
- Cost account manager responsible for support to manufacturing - direction, redline drawings, failure analysis/corrective action.



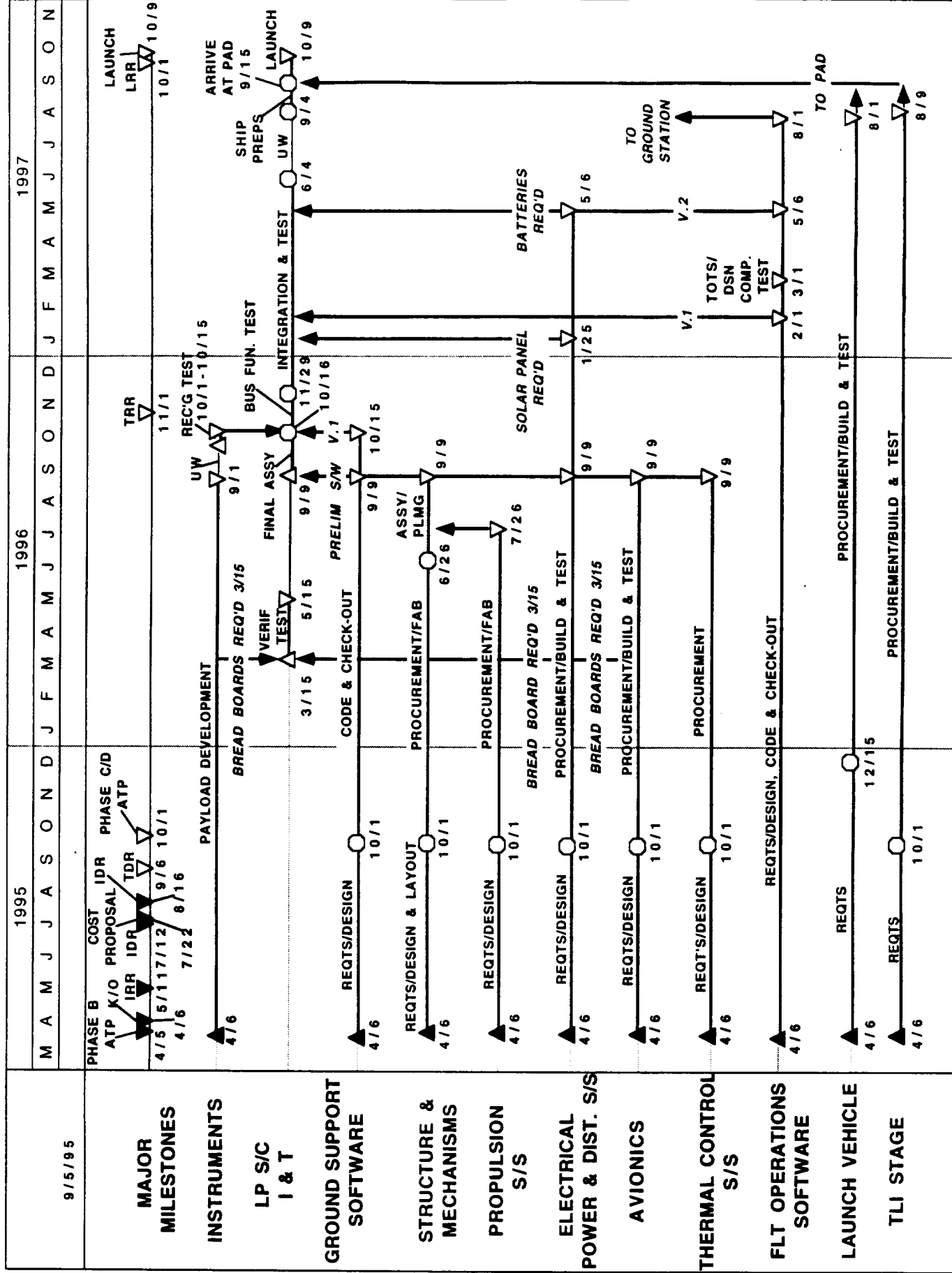
Schedule

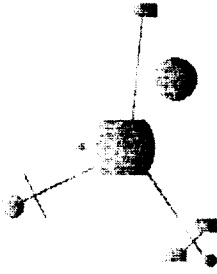
Program Management

LOCKHEED MARTIN

- Phase B to prepare for design release to Production/Procurement on 10/2/95
- C&DH requires additional development - Critical Path
- Hardware/software integration major milestone - 5/15/95
- All deliveries can be accomplished per preliminary Information
- Spacecraft assembly to include house plumbing, wiring and thermal blanketing.
- Integration and test fully defined. Acoustic/Sine Testing to be revisited.
- Program schedule maintained with change in launch date providing three month contingency

LUNAR PROSPECTOR MASTER SCHEDULE REV. C



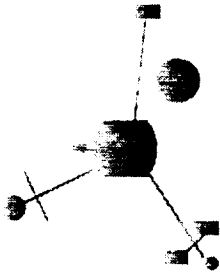


Earned Value

■ Program Management

LOCKHEED MARTIN 

- Detailed schedules will provide milestones on monthly basis which will be valued and tracked for completion.
- Earned value assessment will be accomplished at subcontract and subsystem level and summed for total program evaluation.
- Minimum impact on subsystem personnel resources.

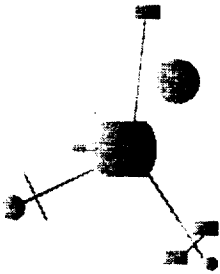


Cost Element Summary

Program Management

LOCKHEED MARTIN

Phase C/D FY96				FY97				
Cost Element	QTR1 O-D	QTR2 J-M	QTR3 A-J	QTR4 J-S	QTR1 O-D	QTR2 J-M	QTR3 A-J	Total C/D
Hours	21,034	28,418	28,735	22,620	24,130	18,513	15,478	158,928
Direct Labor \$'s	675,178	877,957	896,601	732,084	804,542	619,748	512,331	5,118,441
Overhead/G&A \$'s	1,122,094	1,446,978	1,492,084	1,204,343	1,332,993	963,061	780,026	8,341,580
Subtotal Labor \$'s	1,797,272	2,324,935	2,388,685	1,936,427	2,137,535	1,582,810	1,292,357	13,460,021
Subcontract \$'s	699,000	733,000	250,000	200,000	200,000	200,000	40,000	2,322,000
Mat'l \$'s	2,565,000	2,056,000	624,000	500,000				5,745,000
Instrument \$'s	850,000	716,000	363,000	304,000	301,000	288,000	202,000	3,024,000
IWT-LLV \$'s	3,506,000	3,000,000	5,220,000		5,000,000		5,780,000	22,506,000
Support \$'s	300,000	300,000	300,000	300,000	300,000	300,000	300,000	2,100,000
Subtotal N/L \$'s	7,920,000	6,805,000	6,757,000	1,304,000	5,801,000	788,000	6,322,000	35,697,000
Travel \$'s	35,000	35,000	35,000	35,000	34,000	30,000	30,000	234,000
Computer \$'s	129,151	168,804	170,688	134,362	143,331	104,781	87,603	938,719
Fringe \$'s	279,524	370,498	378,366	308,939	339,517	269,590	222,864	2,169,298
Subtotal ODC \$'s	443,674	574,302	584,053	478,301	516,848	404,372	340,467	3,342,017
Subtotal Cost W/O COM	10,160,946	9,704,237	9,729,739	3,718,728	8,455,382	2,775,181	7,954,824	52,499,038
Cost of Money	91,772	132,510	152,401	124,328	150,236	103,145	69,284	823,677
Subtotal Cost Management Reserve	10,252,719	9,836,748	9,882,139	3,843,056	8,605,619	2,878,326	8,024,108	53,322,715
Total Cost	10,252,719	10,359,604	10,143,567	4,104,484	8,867,047	3,139,754	8,285,208	55,152,383
Fee	823,774	898,608	601,168	501,158	472,166	383,364	305,926	3,986,163
Total Price	11,076,493	11,258,212	10,744,735	4,605,642	9,339,213	3,523,118	8,591,134	59,138,546



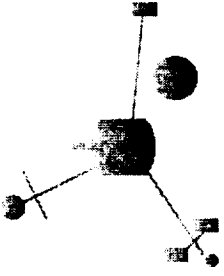
Cost Element Summary (Cont'd)

Program Management

LOCKHEED MARTIN

Phase E FY98

Cost Element	QTR4 J-S	QTR1 O-D	QTR2 J-M	QTR3 A-J	Total E
Hours	8,501	5,255	4,938	4,575	23,269
Direct Labor \$'s	287,710	180,081	168,905	156,333	793,030
Overhead/G&A \$'s	430,317	268,862	237,819	220,117	1,157,114
Subtotal Labor \$'s	718,027	448,943	406,724	376,450	1,950,144
Subcontract \$'s					0
Mat'l \$'s					0
Instrument \$'s	212,000	189,000	192,000	186,000	779,000
IWT-LLV \$'s					0
Support \$'s					0
Subtotal N/L \$'s	212,000	189,000	192,000	186,000	779,000
Travel \$'s	30,000	30,000	15,000	15,000	90,000
Computer \$'s	48,117	29,742	27,750	25,713	131,323
Fringe \$'s	125,154	78,335	71,109	65,816	340,415
Subtotal ODC \$'s	203,271	138,078	113,859	106,529	561,737
Subtotal Cost W/O COM	1,133,298	776,021	712,583	668,979	3,290,881
Cost of Money	33,435	20,808	17,536	16,230	88,010
Subtotal Cost Management Reserve	1,166,734	796,829	730,119	685,210	3,378,891
Total Cost	1,166,734	796,829	730,119	685,210	3,378,891
Fee	142,458	97,293	89,148	83,664	412,563
Total Price	1,309,192	894,122	819,266	768,874	3,791,454



Program Controls

■ Program Management

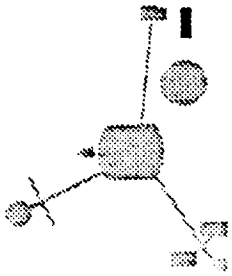
LOCKHEED MARTIN



- Labor and dollar budgets provided to cost account managers (CAMs).
- Labor tapes provided to CAMs on monday morning.
- Milestone status provided by CAMs on continuous basis.
- All costs monitored by APM-Controls on weekly basis.
- “Real time” visibility provided to project manager for timely action.

8.0 SYSTEMS REQUIREMENTS

M. SMITH



System Engineering

LOCKHEED MARTIN

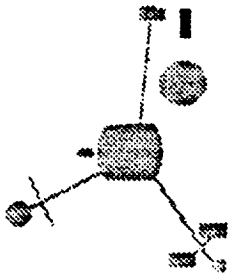


Technical Design Review

System Engineering

Mark Smith

6 - 7 September 1995



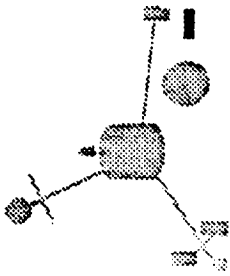
System Engineering Charter

System Engineering

LOCKHEED MARTIN



- Generate Mission CEI Spec (Level 1) & Spacecraft CEI Spec (Level 2)
- Integrate & Coordinate preparation of three Interface Control Documents:
 - Spacecraft to Science Instruments
 - Spacecraft to Launch Vehicle
 - Spacecraft to Mission Operations
- Coordinate and Issue Performance Budgets:
 - Mass budgets
 - Electrical Power budgets
 - Delta V budgets
- Coordinate Design and Verification Requirements Flow-down, from Mission Spec, to Systems, Subsystems and Component Specs
- Assist PI and Project Manager in synthesizing Program Plan, and assembling detail tasks, schedules, cost budgets and status reports
- Supervise the generation of Plans, including Risk Mitigation, Safety, Reliability, etc..



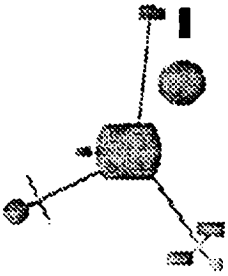
Primary Design Requirements

System Engineering

LOCKHEED MARTIN



Mission Requirements	Specific Value	Margin
Payload power bus voltage	+28Vdc	N/A
Payload peak power	23 W	34 W
Payload orbit average power	17 W	40 W
Spacecraft power	162 W	40 W
Payload total weight	21.5 kg	N/A
Spacecraft weight Empty	TBR	TBR
Spacecraft fueled mass	233 kg	150 kg
Propulsion ΔV	1090 m/s	240 m/s
Science & engineering downlink data rate	3424 bps	176 bps
Engineering command	61	67
Pointing knowledge (post-processing)	$\pm 0.5^\circ$	$\pm 0.2^\circ$
Orbit altitude	901000km	N/A
Orbit inclination	51	N/A
Spacecraft lifetime design requirement	1 year	>2 years



Specification Status

System Engineering

LOCKHEED MARTIN



System Specifications:

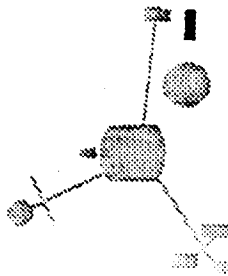
- Spacecraft System - CEI Specification is released
- Launch Vehicle - LLV Requirements Document issued
- Mission-Ops System - CEI Spec in review cycle
- Science Instruments - SI's to Spacecraft ICD is released
- Trans-Lunar Injection Stage - CEI Specification is released

Subsystem Specifications

- All Subsystem CEI Specs are in final coordination review
- Audit of design & verification requirements flowdown in process
- Changes to be incorporated prior to 30 September

Component Specifications

- Two long lead-time component specs released
- Five [TBR] more pending; release scheduled during Ph. C/D



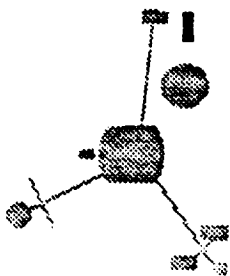
Mission Timeline

System Engineering

LOCKHEED MARTIN



Time from separation yr/day /hour/min	Major Events
-0/000/00/16	LLV 2 launch
0/000/00/00	Separation from spinning kick-stage
0/000/00/30	Spin-down to 12 RPM
0/000/00/41	Re-orientation
0/000/01/12	Science instrument turn-on initiate
0/000/05/20	Switch to medium gain antennae
0/000/16/00	First mid-course maneuver
0/000/22/10	Boom deployment
0/000/23/12	Spin-up to 12 RPM
0/003/14/00	Second mid-course maneuver
0/004/13/46	Initiate first LOI
0/005/13/48	(Lunar Prospector in 24 hr. capture orbit)
0/006/13/50	Initiate second LOI burn
	(Lunar Prospector in 4 hr. orbit)
	Initiate third LOI burn
	(Lunar Prospector in 118 min. - 100 km mapping orbit)
0/006/15/52	Start one year mapping program
0/050/??/??	Initiate Lunar Orbit maintenance burn
0/094/??/??	Initiate Lunar Orbit maintenance burn
0/138/??/??	Initiate Lunar Orbit maintenance burn
0/??/?/01/11	Spacecraft in eclipse survival mode
0/??/?/08/47	Re-start mapping
0/2??/?/??	Initiate Lunar Orbit maintenance burn
1/006/15/52	End of nominal mapping mission
1/006/15/53	Begin extended mapping mission
??/?/?/??	End of mission



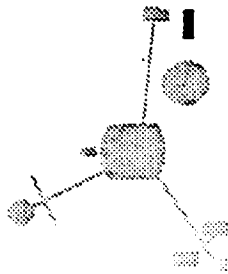
Primary System Performance Parameters

System Engineering

LOCKHEED MARTIN



Mission Requirements	Specific Value	Current Margin
Payload power bus voltage	+28Vdc	N/A
Payload peak power	23 W	34 W
Payload orbit average power	17 W	40 W
Spacecraft power	162 W	40 W
Payload total weight	21 kg	N/A
Spacecraft design weight Empty	165 kg	20 kg
Spacecraft fueled mass	303 kg	150 kg
Propulsion ΔV	1190 m/s	240 m/s
Science & engineering downlink data rate	3424 bps	176 bps
Engineering commands	61 TBR	67 TBR
Pointing knowledge (post-processing)	$\pm 0.5^\circ$	$\pm 0.2^\circ$
Orbit altitude	100 km	N/A
Orbit inclination	10°	$\pm 5^\circ$
Spacecraft lifetime design requirement	1 year	>2 years



Design Overview

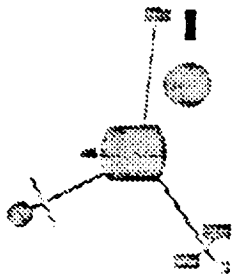
System Engineering

LOCKHEED MARTIN



Science Instruments / Experiments						
Experiment	Mass (kg)	Power (W)	FOV	Data Rate	Pointing (°)	RPM
GRS	6.6	3.0	4π	688 bps	±3	N/A
NS*	2.2	2.5	4π	50 bps	N/A	N/A
APS*	0.9	12.5	4π	181 bps	N/A	N/A
MAG/ER*	6.2	4.5	4π	670 bps	±0.5	12 ±0.7
DGE	N/A	N/A	4π	N/A	N/A	slow

Spacecraft Design Summary	
Structure	Graphite-Epoxy
Propulsion	Hydrazine mono-propellant system; six 22N engines; multiple redundancy
Attitude Control	Uses propulsion subsystem
Power	206 W EOL solar arrays; 7 A-hr NiH2 battery
Thermal Control	Passive and thermostat controlled heaters
Communications	S-band medium gain and low gain antennas
Software	Ground control of spacecraft



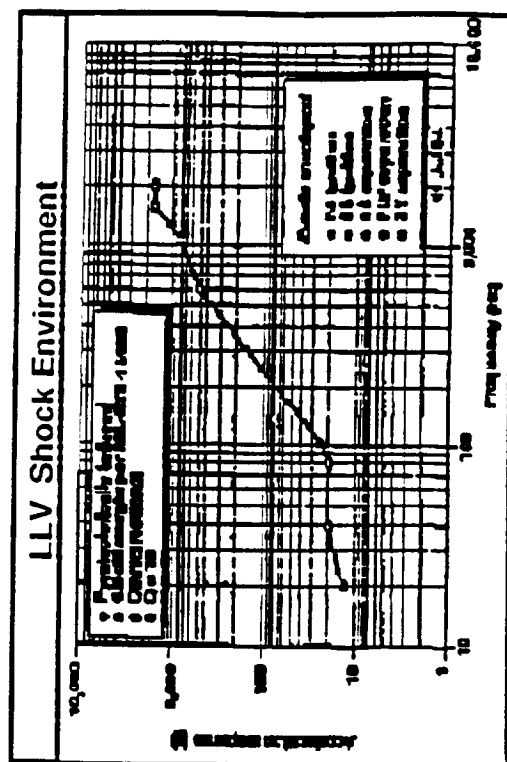
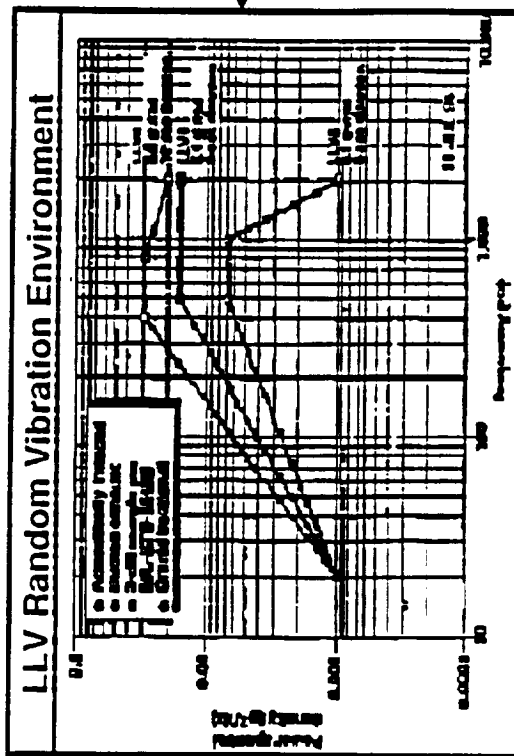
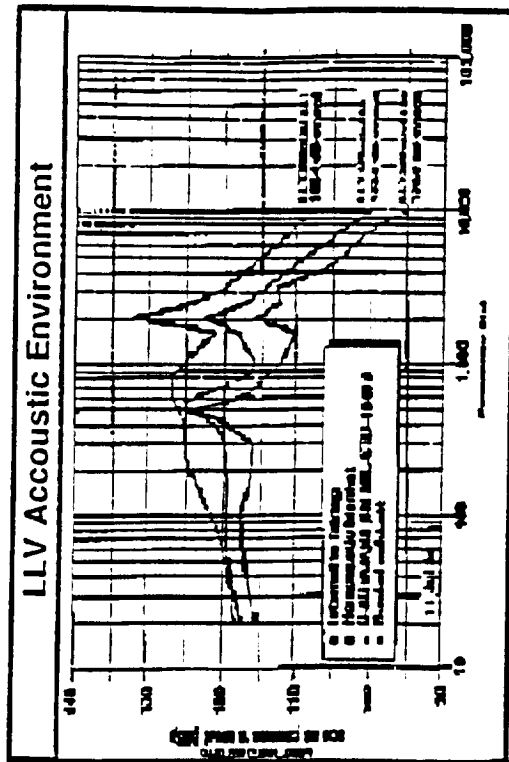
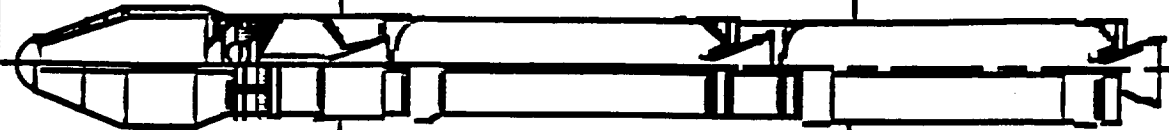
Launch System Limit Load Environment

System Engineering

LOCKHEED MARTIN

LLV2

Launch Loads: Dynamic Mode Frequencies:	axial	lateral
	+1 g, -7 g > 30 Hz	±2 g > 12 Hz



Random Vibration Design/Test Environments

System Engineering

LOCKHEED MARTIN



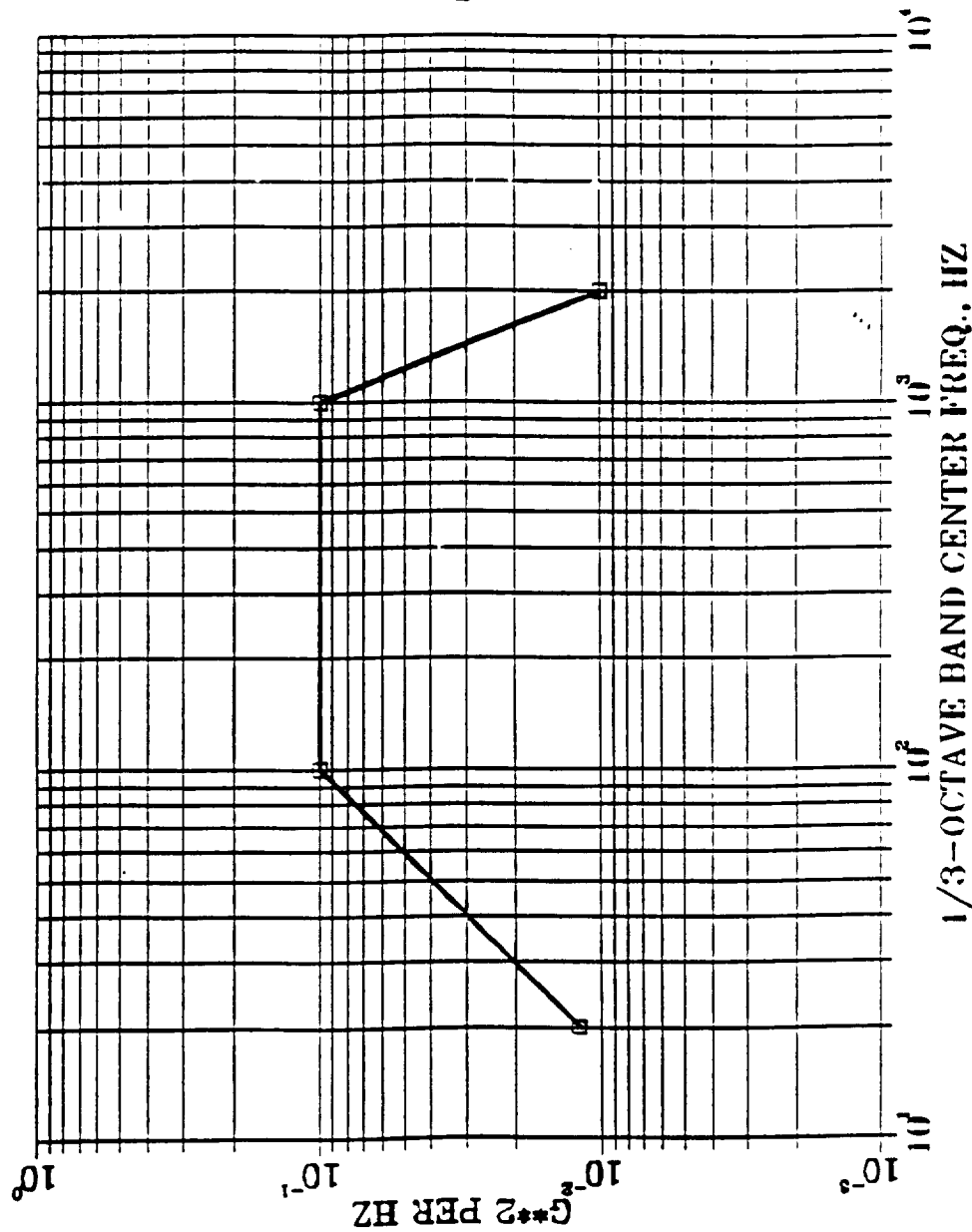
FREQ (HZ)	LEVEL (G**2/HZ)
20.	.012
100.	.10
1000.	.10
2000.	.01
O.A.	11.3 GRMS

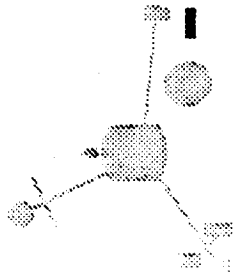
LEGEND

□ PROTO-QUAL : DUR=60 SECS

OVERALL LEVELS (GRMS)

□ 11.3

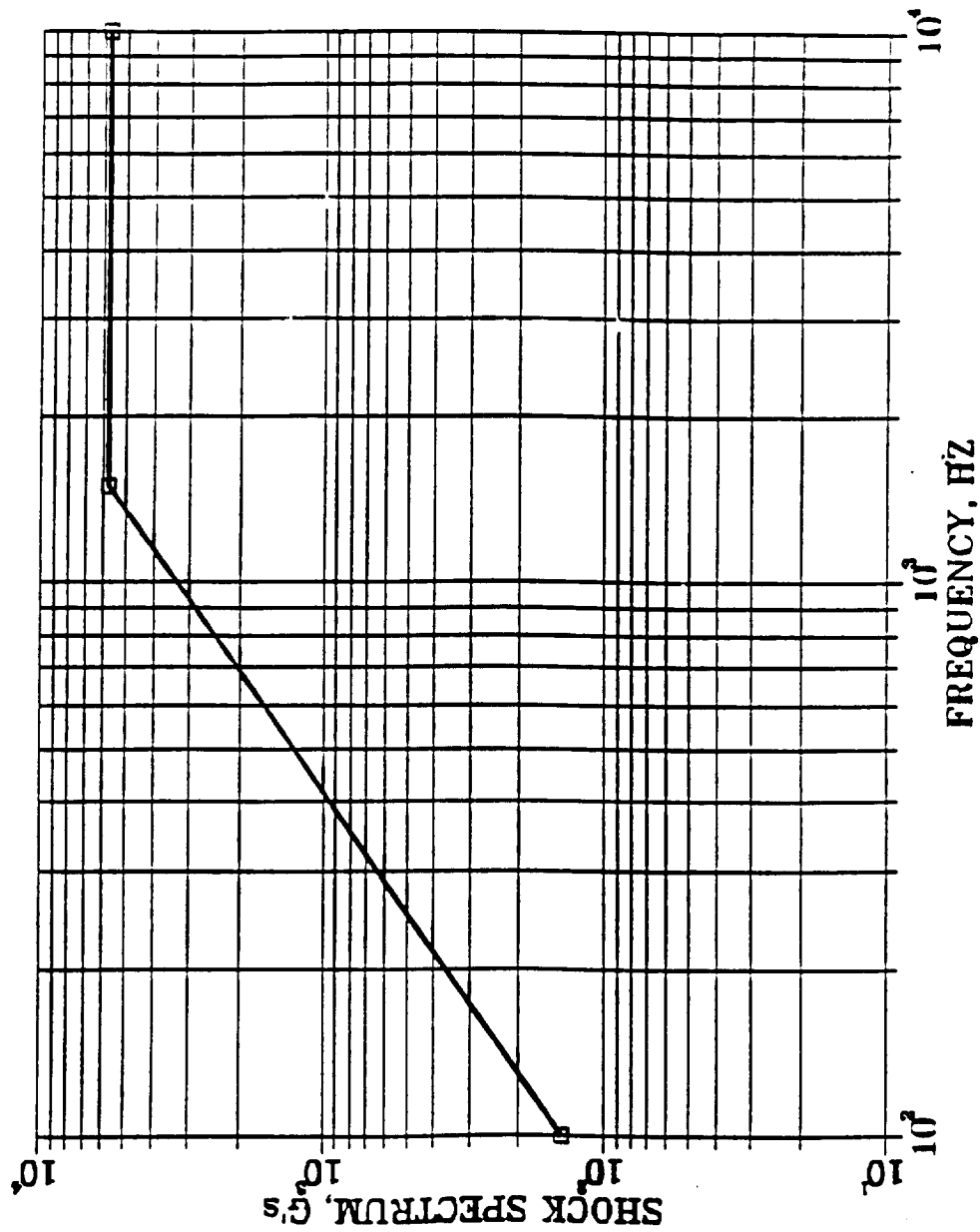




Shock Design/Test Spectrum

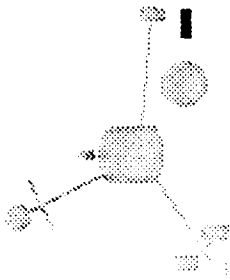
System Engineering

LOCKHEED MARTIN



LEGEND

□ PROTO-QUAL SPEC



Launch & Ascent Design Limit Loads

System Engineering

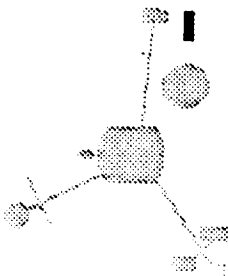
LOCKHEED MARTIN



FLIGHT EVENT	AXIAL	LATERAL	ANGULAR
	g's	g's	rad/sec ²
LAUNCH/FIRST STAGE IGNITION	-1.3/+3.9	± 1.9	± 10
FIRST STAGE MOTOR RESONANCE	2.6 ± 1.3	± 1.9	± 10
WIND GUST	2.6	± 3.2	± 10
FIRST STAGE MOTOR RESONANCE/WIND GUST	2.6 ± 1.3	± 3.9	± 10
FIRST STAGE MAXIMUM ACCELERATION	2.6	± 2.6	± 10
SECOND STAGE IGNITION	-1.3/+7.7	± 1.9	± 10
SECOND STAGE MOTOR RESONANCE	5.2 ± 3.9	± 3.2	± 10
SECOND STAGE MAXIMUM ACCELERATION	10.3	± 2.6	± 10
ORBUS 21 IGNITION	-2.6/+6.4	± 2.6	± 10
ORBUS 21 MAXIMUM ACCELERATION	9.0	± 1.3	± 10
ENVELOPE	-2.6/+10.3	± 3.9	± 10

NOTES:

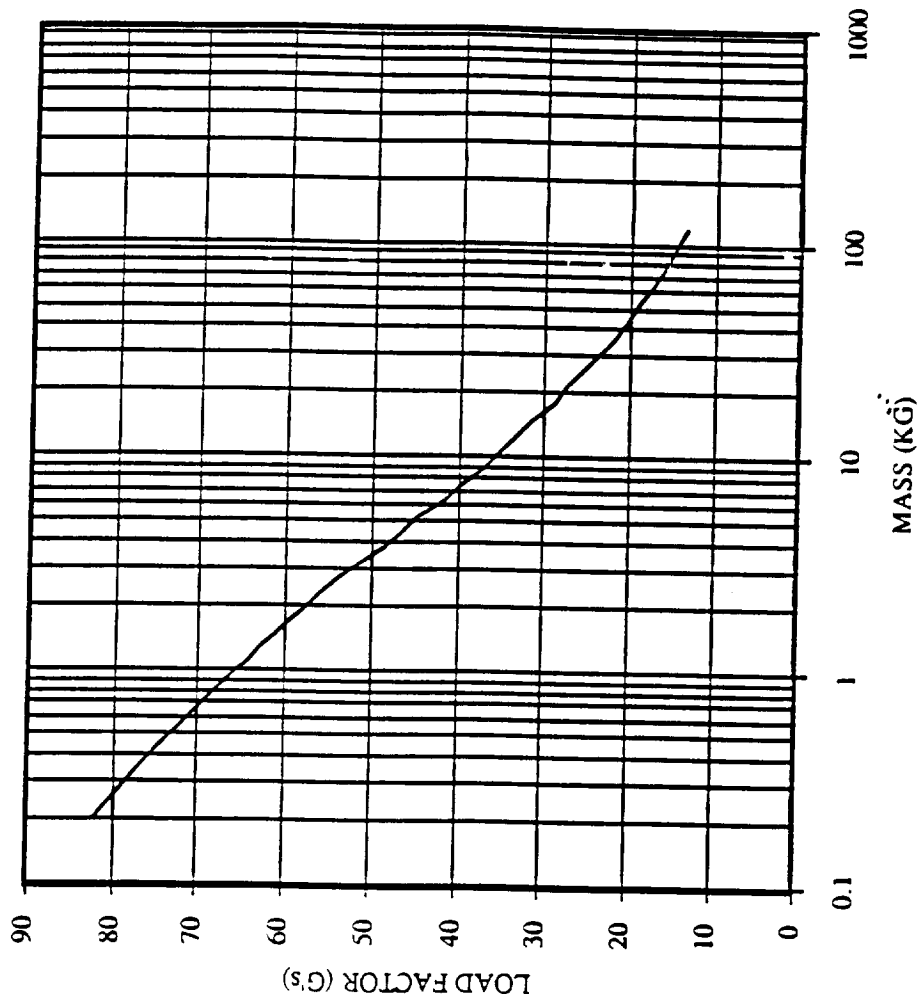
1. LOAD FACTORS HAVE 3 SIGMA PROBABILITY OF NOT BEING EXCEEDED.
2. POSITIVE AXIAL LOAD FACTOR ACT'S AFT AT SPACECRAFT CG.
3. APPLY LATERAL LOAD FACTOR SIMULTANEOUSLY IN SPACECRAFT X/Y AXES.
4. APPLY ANGULAR ACCELERATION SIMULTANEOUSLY ABOUT SPACECRAFT X/Y AXES AT SPACECRAFT CG.
5. LOAD FACTORS AND ROTATIONAL ACCELERATION ACT SIMULTANEOUSLY.

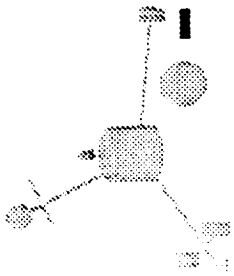


System Engineering

Design Limit Load Factors For Small Assemblies

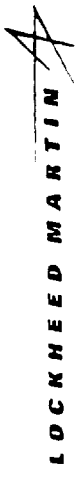
LOCKHEED MARTIN



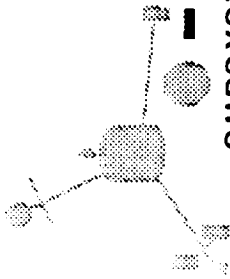


— System Engineering

Mass Properties



*[Expect about four charts
for these data]*



— System Engineering

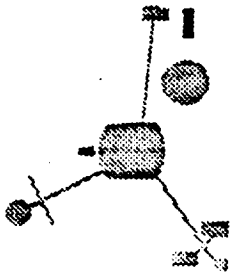
Mass Budgets With Contingency

LOCKHEED MARTIN

SUBSYSTEM

	MASS (KG) NO CONTINGENCY	CONTINGENCY	MASS (KG) WITH CONTINGENCY
THERMAL CONTROL	8.30	20%	9.96
PROPULSION	25.24	10%	29.03
C&DH	13.05	20%	15.66
ELECTRICAL POWER	26.20	15% exc. Wire 25%	31.09
STRUCTURE LESS BOOMS	38.15	15%	45.78
BOOMS, BALANCE & PAYLOAD WIRE	7.33	20% exc. Wire 25%	7.82
SCIENCE INSTRUMENTS	21.26	0%	21.26
MASS EMPTY	139.53	15%	160.60
BALLAST	3.97		5.85
MASS EMPTY-BALANCED	143.50		166.45
PROPELLANT & PRESSURANT	138.25		138.25
SPACECRAFT MASS AT LAUNCH	281.75		304.70
LP/STAR37 ADAPTER ASSY	30.00		30.00
STAR37 XFP LOADED	948.30		948.30
SAFE ARM, SPIN ROCKET & TIMER ASSYS	9.40		9.40
LLV/STAR37 ADAPTER (UPPER SECTION)	20.00		20.00
SYSTEM MASS AT LAUNCH	1289.45		1312.40

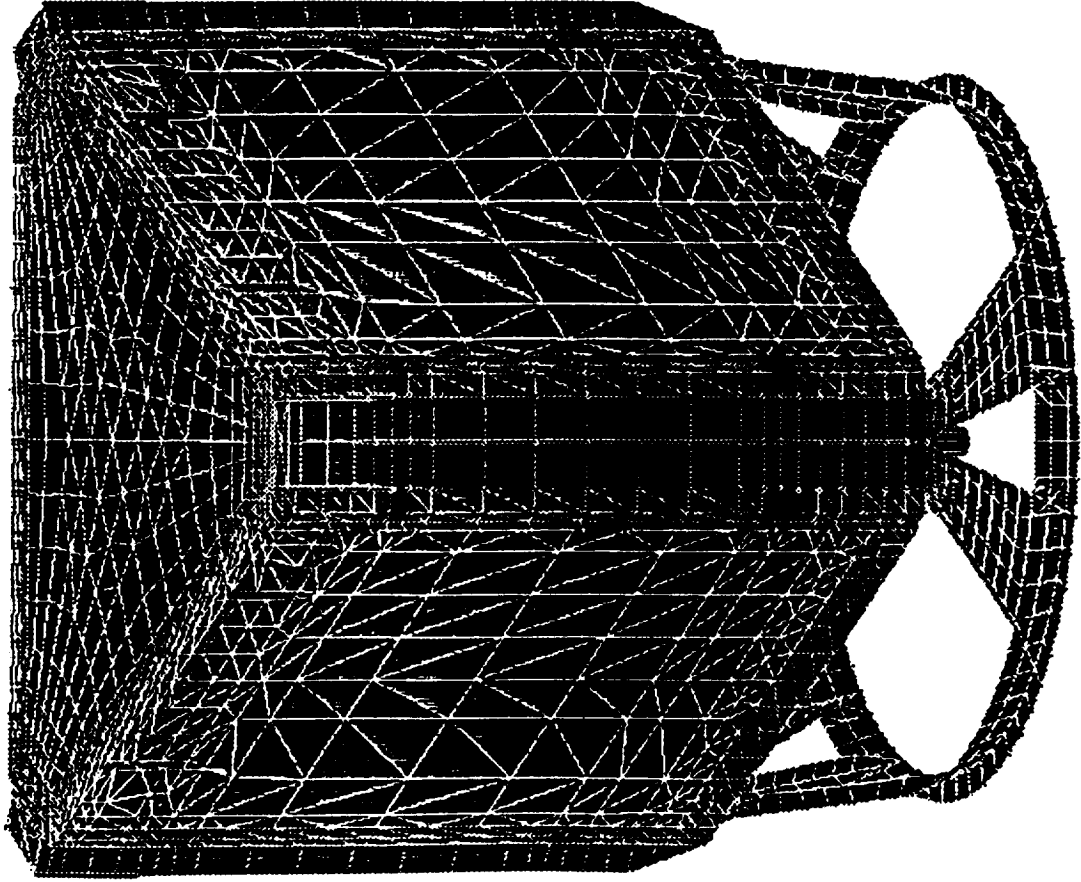
* LLV/STAR37 ADAPTER (LOWER SECTION) = 115 KG NOT INCLUDED IN THIS SUMMARY



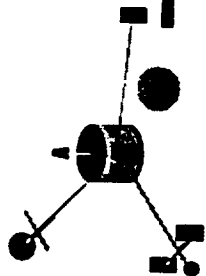
SmallSat Finite Element Model

System Engineering

LOCKHEED MARTIN



- Prototype Primary Structure Is Modeled & Analyzed
- Being Considered For Use As Main Element of Dynamic Test Bed
- Also Potentially Usable As Primary Structural Member On Flight Vehicle
- If Not Usable, Costly Tooling Is Available To Fabricate LP-Tailored Prime Structure
- Provides Major Schedule Relief, Both In Dynamic Response Loads Verification & In Vehicle Assembly Critical Path

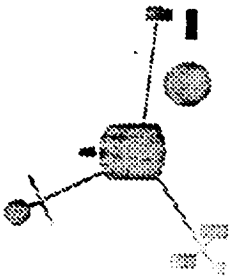


ELECTRICAL POWER BUDGET

LOCKNEED MARTIN

Electrical Power

SUBSYSTEM		AVERAGE POWER DEMAND (Watts)									
		Ascent	S/C Sep. & Chk-Out	SI Calibr.	Cruise (SI's Off)	Lunar Orb. Insertion	Orbit Sunlight	Orbit Nightpass	Lunar Eclipse		
Struct. and Mechanisms	Baseline (W)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	w. Cont'cy (W)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	%-Contingency	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Attitude Control	Baseline (W)	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		
	w. Cont'cy (W)	0.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1		
	%-Contingency	N/A	5%	5%	5%	5%	5%	5%	5%		
Electrical Power (EPS)	Baseline (W)	3.5	11.3	12.4	12.4	12.4	12.4	12.4	8.0		
	w. Cont'cy (W)	3.7	12.9	14.3	14.3	14.3	14.3	14.3	9.5		
	%-Contingency	5%	14%	16%	16%	16%	16%	16%	19%		
C & DH	Baseline (W)	0.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0		
	w. Cont'cy (W)	0.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0		
	%-Contingency	N/A	30%	30%	30%	30%	30%	30%	30%		
Communications	Baseline (W)	0.0	37.8	37.8	37.8	37.8	37.8	37.8	37.8		
	w. Cont'cy (W)	0.0	39.7	39.7	39.7	39.7	39.7	39.7	39.7		
	%-Contingency	N/A	5%	5%	5%	5%	5%	5%	5%		
Thermal Control	Baseline (W)	0.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0		
	w. Cont'cy (W)	0.0	19.5	19.5	19.5	19.5	19.5	19.5	19.5		
	%-Contingency	N/A	30%	30%	30%	30%	30%	30%	30%		
Propulsion Including TLI	Baseline (W)	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	w. Cont'cy (W)	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	%-Contingency	30%	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Payloads	Baseline (W)	0.0	0.0	17.0	17.0	17.0	17.0	17.0	17.0		
	w. Cont'cy (W)	0.0	0.0	17.0	17.0	17.0	17.0	17.0	17.0		
	%-Contingency	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
TOTAL	Baseline (W)	5.0	75.1	93.2	93.2	93.2	93.2	88.8	88.8		
	w. Cont'cy (W)	5.7	86.2	104.6	104.6	104.6	104.6	99.8	99.8		
	%-Contingency	14%	15%	12%	12%	12%	12%	12%	12%		

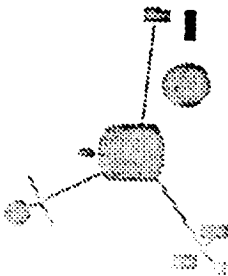


System Engineering

Quality Assurance Requirements Audit

LOCKHEED MARTIN

- QA and design verification requirements in System & Subsystem CEI specs are being reviewed for essential compliance with proven space systems development, acquisition, and operational deployment practices.
- This audit is carried out independently by both System Engineering and Quality Assurance.
- Results of both audits are to be reported by separate Eng'g. Memo's, with sign-offs by the PI and the Project Mgr.
- Upon satisfactory cleanup the affected specs will be released.
- This task is scheduled for completion by 30 September



System Engineering Support Tasks

System Engineering

LOCKHEED MARTIN



- Assembles, and maintains, the Program Management Plan
- Performs design & verification requirements coordination, and coordinates preparation of specifications/drawings for supplier/subcontractor technical direction.
- Aids the Project Manager in monitoring cost and schedule performance.
- Disburses the budgets for Space Technology analytical and test support, and for the "ilities" functions, as is necessary and cost-effective in a well balanced Space System acquisition program.
- Provides for, and oversees, configuration management control, the data library, documentation dissemination, and the preparation of special planning documentation.

**LUNAR PROSPECTOR
TECHNICAL DESIGN REVIEW**

September 6 & 7, 1995

Thursday

LOCKHEED MARTIN



**LOCKHEED MARTIN MISSILES & SPACE CO
SPACE SYSTEMS DIVISION
SUNNYVALE, CA 94089-3504**

Technical Design Review

September 6, 1995

■ Introduction

LOCKHEED MARTIN

Agenda

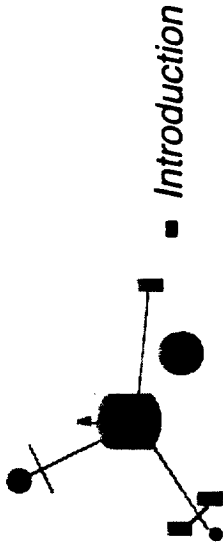
- | | | |
|---|-----------------------|------|
| 1. Welcome/Introduction | M. Saunders/F. Martin | 8:00 |
| 2. Ames Mission Management
Office Rolls & Responsibilities | S. Hubbard | 8:15 |
| 3. Program Overview/Requirements/
Description | A. Binder | 8:30 |

Break

- | | | |
|-------------------|--------------|-------|
| 4. Project Status | A. Binder | 10:00 |
| 5. Management | T. Dougherty | 11:00 |

Lunch

- | | | |
|-------------------------------|-----------|------|
| 6. Science Goals & Objectives | A. Binder | 1:00 |
| 7. Science Instruments | A. Binder | 2:00 |
| 8. Systems Requirements | M. Smith | 4:00 |



■ Introduction

Technical Design Review

September 7, 1995

LOCKHEED MARTIN



Agenda

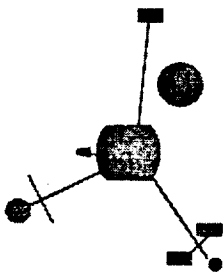
- | | | |
|--|--------------|-------|
| 9. Spacecraft Subsystems | T. Dougherty | 8:00 |
| 10. Systems Assembly, Integration & Test | K. Foster | 11:00 |

Lunch

- | | | |
|---------------------|-----------------------|------|
| 11. Launch Vehicle | R. Lynch | 1:00 |
| 12. Ground System | T. Bridges/M. Stewart | 2:00 |
| 13. Operations | A. Binder | 2:20 |
| 14. SR&QA | R. Fullerton | 2:30 |
| 15. Opportunities | A. Binder | 2:50 |
| 16. Risk Management | T. Dougherty | 3:10 |
| 17. Program Costs | T. Dougherty | 3:30 |
| 18. Closing Remarks | A. Binder | 4:00 |

9.0 SPACECRAFT SUBSYSTEMS

T. DOUGHERTY



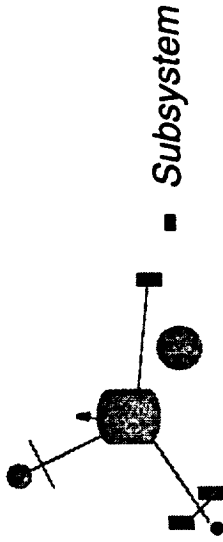
■ Subsystems

Subsystems

LOCKHEED MARTIN



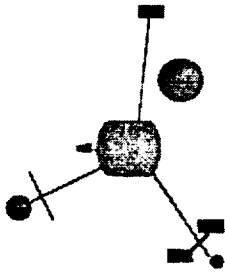
- Structures and Mechanisms
- Thermal
- Electrical Power
- Propulsion
- Avionics
- Software



Subsystem Format

LOCKHEED MARTIN

- Function
- Key Requirements
- System Description
- Hardware Description
- Test Program
- Schedule
- Issues



Structures & Mechanisms

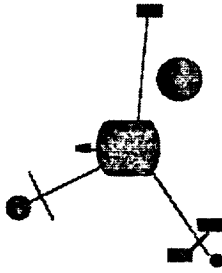
LOCKHEED MARTIN



Structures & Mechanisms

T. Chinn

Page 1
TC 9/6/95

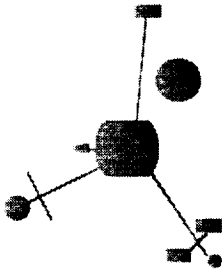


STRUCTURES FUNCTION

Structures & Mechanisms

LOCKHEED MARTIN

- The primary S/C structure consist of an external structure, an internal structure, an equipment shelf, instrument masts, and a separation mechanism.
- The external structure will provide a mounting surface for solar panels, sun sensors and limb crossing sensor
- The internal structure will provide a mounting surface for propellant tanks, equipment shelf and instrument masts
- The equipment shelf is mounted on the forward surface of the internal sturcture. It will provide mounting surfaces for a battery, instrument electronics, transponders and spacecraft electronics
- The instrument masts provide support and deployment for the scientific instruments



REQUIREMENTS

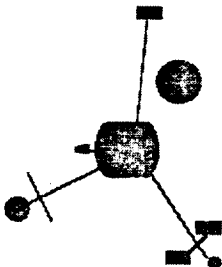
Structures & Mechanisms

LOCKHEED MARTIN

- Safety factor > 1.1 under worst loading conditions
- Science instrument's mass is 21 kg
- Science instruments are mounted on 3 deployable masts
- Mast length is 2.5 m
- Dry mass < 150 kg (Mass + contingency)
- Spin stabilized
- Minimum number of subsystems requiring deployment
- Fixed base frequency constraints

	<u>ASSEMBLY</u>	<u>AXIAL (Hz)</u>	<u>LATERAL (Hz)</u>
Spacecraft/STAR 37		>30	>12
Propellant/Tank		30 < f b	<40 or 60*

* Applies to any axis



REQUIREMENTS

Structures & Mechanisms

LOCKHEED MARTIN

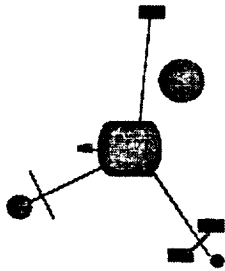


LIMIT LOAD FACTOR LIFTOFF AND ASCENT

ON-ORBIT EVENT	TRANSLATION		ANGULAR	
	AXIAL	LATERAL	ROLL	LATERAL
	g's	g's	rad/sec ²	rad/sec ²
KICK MOTOR SPIN-UP ^{1,8}	± 0.2	± 0.3	+7.0	± 0.1
KICK MOTOR IGNITION ^{1,8}	-4.3/+10.7	± 4.3	TBS	± 10
KICK MOTOR BURN-OUT ^{1,8}	± 13.3	± 1.7	--	± 4.0
SPACECRAFT DESPIN ^{2,5}	± 0.1	± 0.1	-1.0	± 0.5
BOOM DEPLOYMENT ^{3,5}	± 0.1	± 0.2	--	± 0.5
SPACECRAFT SPIN-UP ^{4,5}	± 0.1	± 0.1	+0.2	± 0.5
ON-ORBIT OPERATIONS ^{5,6,7}	± 0.2	± 0.2	± 0.2	± 0.5

NOTES:

1. LOAD FACTORS AND ANGULAR ACCELERATIONS ACT SIMULTANEOUSLY WITH A 6.28 RAD/SEC ROLL ANGULAR VELOCITY.
2. LOAD FACTORS AND ANGULAR ACCELERATIONS ACT SIMULTANEOUSLY WITH A 6.28 OR 1.26 RAD/SEC ROLL ANGULAR VELOCITY.
3. LOAD FACTORS AND ANGULAR ACCELERATIONS ACT SIMULTANEOUSLY WITH A 1.26 OR 0.18 RAD/SEC ROLL ANGULAR VELOCITY.
4. LOAD FACTORS AND ANGULAR ACCELERATIONS ACT SIMULTANEOUSLY WITH A 0.18 OR 1.37 RAD/SEC ROLL ANGULAR VELOCITY.



REQUIREMENTS

Structures & Mechanisms

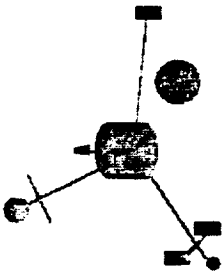
LOCKHEED MARTIN

LIMIT LOAD FACTOR TRANS-LUNAR-INSERTION-ORBIT

FLIGHT EVENT	AXIAL	LATERAL	ANGULAR
	g's	g's	rad/sec ²
LAUNCH/FIRST STAGE IGNITION	-1.3/+3.9	± 1.9	± 10
FIRST STAGE MOTOR RESONANCE	2.6 ± 1.3	± 1.9	± 10
WIND GUST	2.6	± 3.2	± 10
FIRST STAGE MOTOR RESONANCE/WIND GUST	2.6 ± 1.3	± 3.9	± 10
FIRST STAGE MAXIMUM ACCELERATION	2.6	± 2.6	± 10
SECOND STAGE IGNITION	-1.3/+7.7	± 1.9	± 10
SECOND STAGE MOTOR RESONANCE	5.2 ± 3.9	± 3.2	± 10
SECOND STAGE MAXIMUM ACCELERATION	10.3	± 2.6	± 10
ORBUS 21 IGNITION	-2.6/+6.4	± 2.6	± 10
ORBUS 21 MAXIMUM ACCELERATION	9.0	± 1.3	± 10
ENVELOPE	-2.6/+10.3	± 3.9	± 10

NOTES:

1. LOAD FACTORS HAVE 3 SIGMA PROBABILITY OF NOT BEING EXCEEDED.
2. POSITIVE AXIAL LOAD FACTOR ACTS AFT AT PAYLOAD CG.
3. LATERAL LOAD FACTOR CAN ACT IN ANY DIRECTION IN PAYLOAD XY PLANE.
4. APPLY ANGULAR ACCELERATION IN PLANE NORMAL TO LATERAL LOAD FACTOR.
5. LOAD FACTORS AND ROTATIONAL ACCELERATION ACT SIMULTANEOUSLY.



REQUIREMENTS

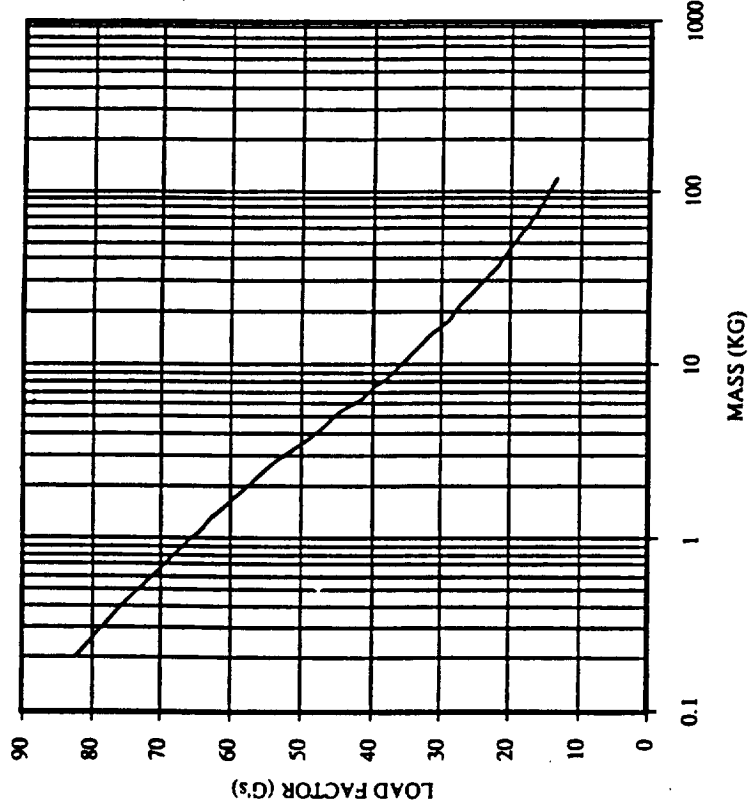
Structures & Mechanisms

LOCKHEED MARTIN

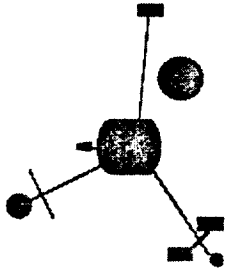
DESIGN LIMIT LOAD FACTOR

FOR

SECONDARY STRUCTURE/COMPONENTS



5. LATERAL LOAD FACTOR IS ALONG SPACECRAFT X AXIS. ANGULAR ACCELERATION ABOUT SPACECRAFT X AXIS.
6. LOAD FACTORS AND ANGULAR ACCELERATIONS ACT SIMULTANEOUSLY WITH A 1.37 RAD/SEC ROLL ANGULAR VELOCITY.
7. TRANSLATION AND ANGULAR ACCELERATIONS ARE TO BE APPLIED SEPARATELY AND SIMULTANEOUSLY. WHEN APPLYING SIMULTANEOUSLY REDUCE TABULATED VALUES BY ONE-HALF.
8. TABLE 3.2.1-1 NOTES APPLY TO KICK MOTOR EVENTS.



Structures & Mechanisms

LOCKHEED MARTIN

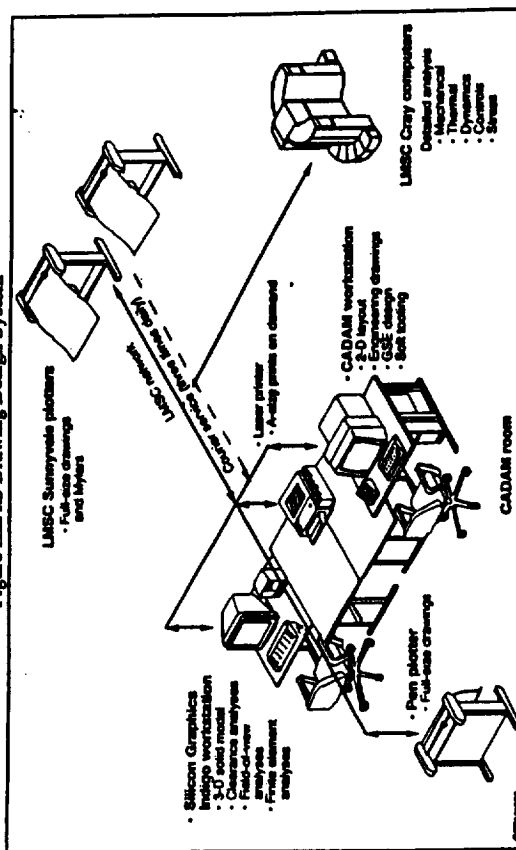
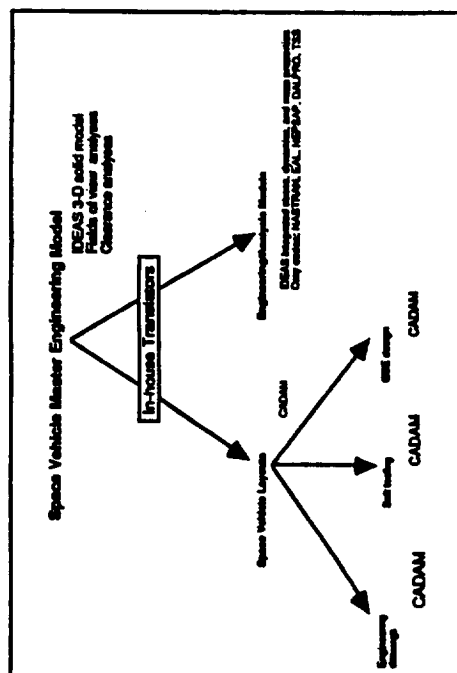


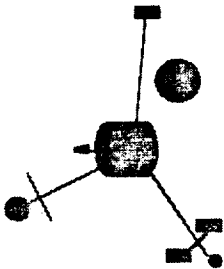
DESIGN



Structures & Mechanisms

LOCKHEED MARTIN

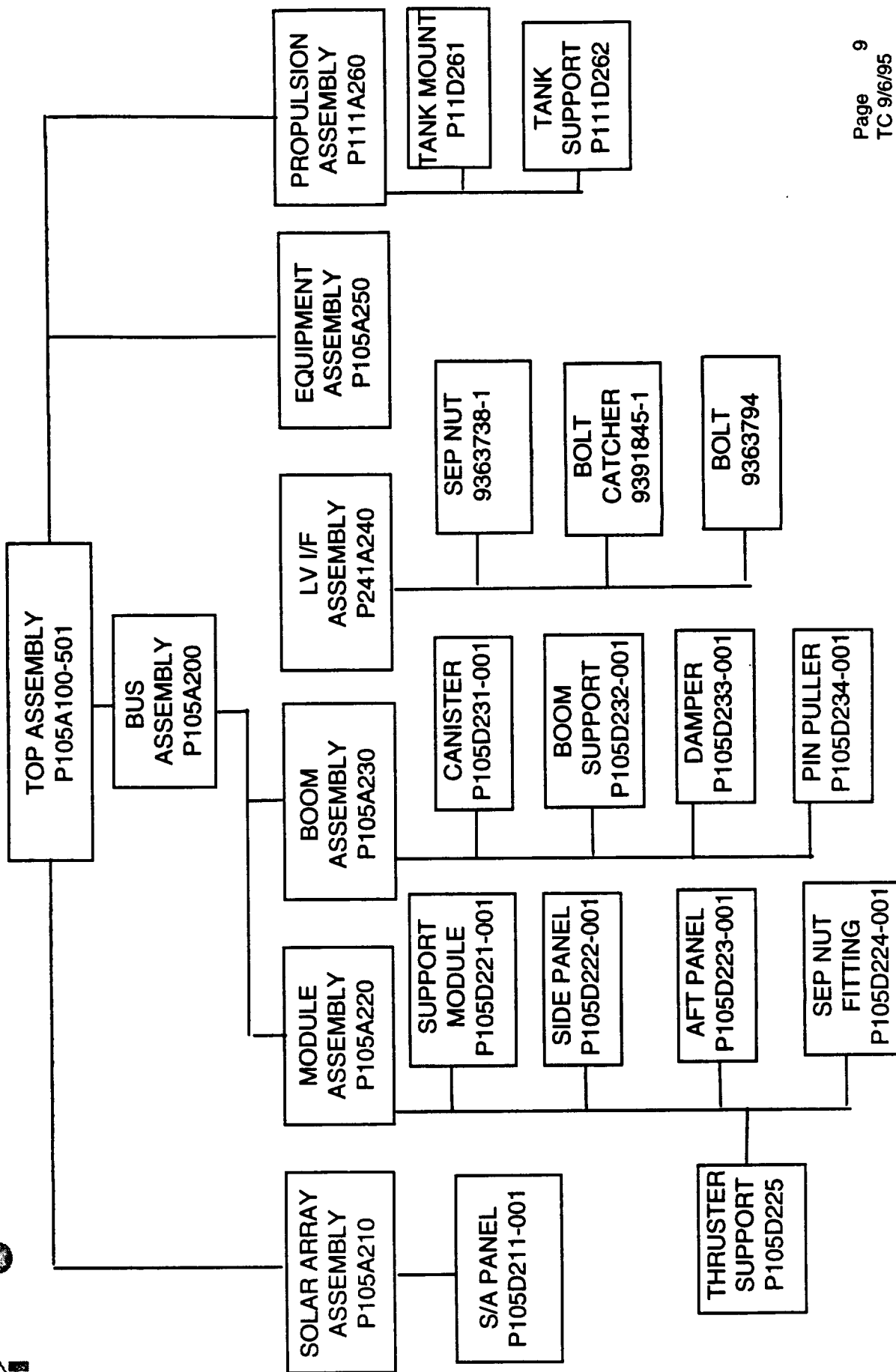


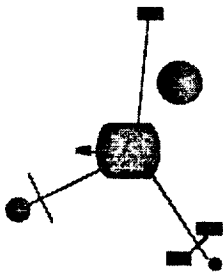


DESIGN DRAWING TREE

Structures & Mechanisms

LOCKHEED MARTIN





Structures & Mechanisms

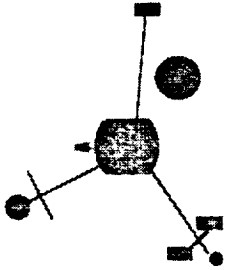
LOCKHEED MARTIN



STRUCTURES & MECHANISMS CHARACTERISTICS

WBS #	Component	Source	Heritage	Quantity	Mass (kg)
2.1.5	Solar Drum Panel	DOWUT	LMMS	3	8.6
2.1.5	Equipment Shelf	DOWUT	LMMS, IRIDIUM®	1	4.8
2.1.5	Support Module	DOWUT	LMMS, IRIDIUM®	1	15.3*
2.1.5	Set Nut/ Bolt Catcher	Hi-Shear	MILSTAR, CRSS	3	2.5
2.1.5	Mast	Able	APSA	3	2.0
2.1.5	Mast Support	DOWUT	LMMS	3	2.7
2.1.5	Propellant Tank Support	DOWUT	LMMS	3	1.0
2.1.5	Antenna Mast Support	DOWUT	LMMS	1	0.25
2.1.5	Mast Release Mechanism	Starsys	IRIDIUM®, CRSS	TBD	TBD
2.1.5	Mast Damper	LMMS	MILSTAR	1	0.2

* Include side panels

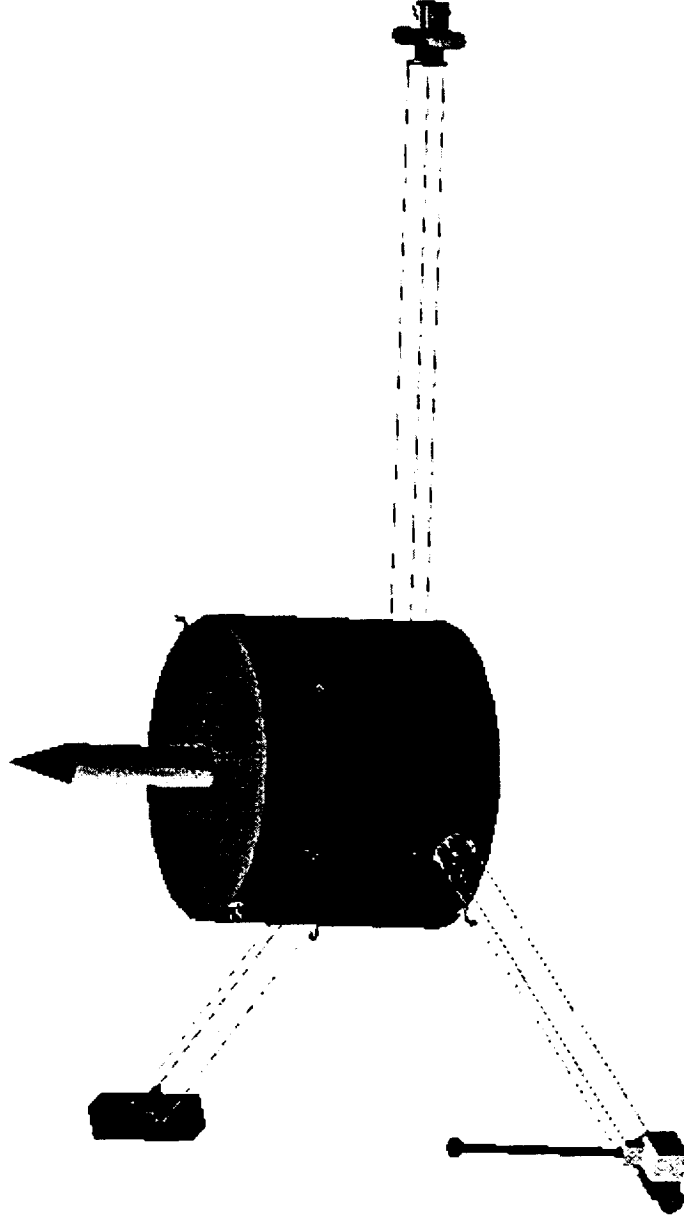


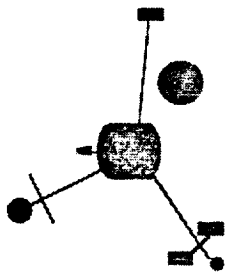
DESIGN

Structures & Mechanisms

LOCKHEED MARTIN

LUNAR PROSPECTOR DEPLOYED



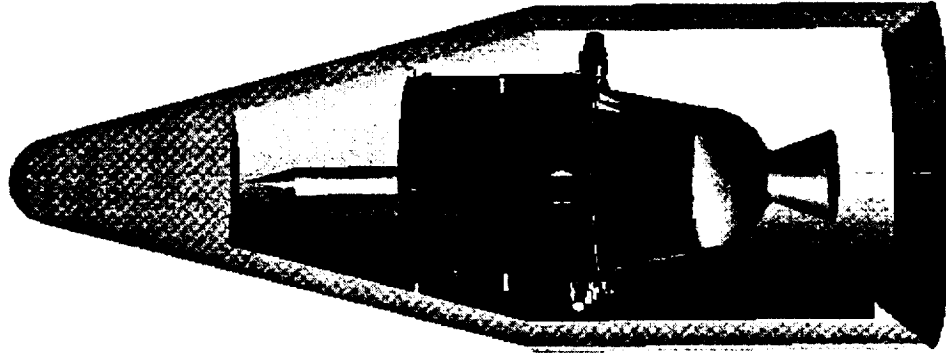


DESIGN

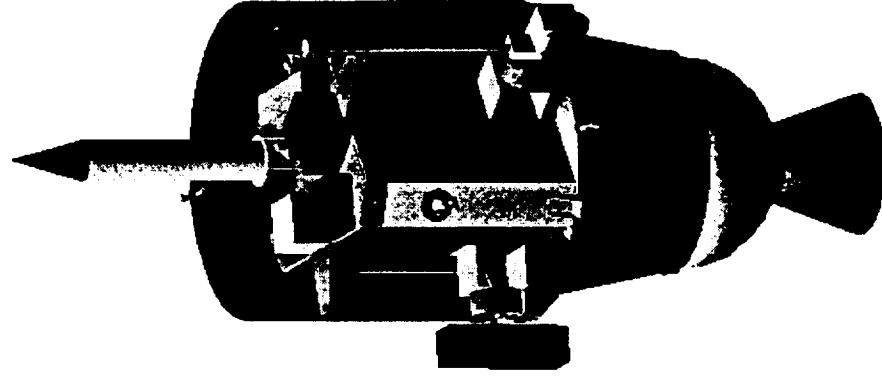
Structures & Mechanisms

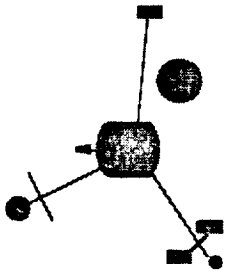
LOCKHEED MARTIN

LUNAR PROSPECTOR STOWED IN LLV2 FAIRING



LUNAR PROSPECTOR STRUCTURES & MECHANISMS





DESIGN

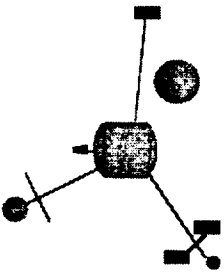
Structures & Mechanisms

Stress Analysis/Margins of Safety

Component	Notes	Load Description	Critical Load Condition	Design Criteria Reference	Margin of Safety	Failure Mode
Adapter at TLI Stage / Launch Vehicle Interface	Ult. Section Loads at Top of Adapter: Axial = 54,050 lb. Shear = 20,470 lb. Moment = 722,400 in.-lb.	Ascent Loads on Spacecraft and TLI Stage	Second Stage Motor Resonance	Table 3.2.1-1	+0.25	Buckling
Adapter at Spacecraft / TLI Stage Interface (2)	Ult. Section Loads at Top of Adapter: Axial = 15,580 lb. Shear = 5,040 lb. Moment = 125,900 in.-lb.	Overall Loads on Spacecraft	Kick Motor Ignition / Burnout	Tables 3.2.1-1 and 3.2.2-2	+0.67 (1)	-
Separation Bolts and Fittings	Ult. Fitting Loads: Axial = 8800 lb. Shear = 1680 lb.	Overall Loads on Spacecraft	Kick Motor Ignition / Burnout	Tables 3.2.1-1 and 3.2.2-2	+0.67 (1)	-
Tank Installation	Internal Support Struts	Ascent Loads on Tanks	Equipment Installation Load Factors	Figure 3.4-1	+0.26	Web Crippling
Sensor Interface to Boom	Gamma Ray Spectrometer is critical case (smallest interface footprint)	Ascent Loads on Sensor	Equipment Installation Load Factors	Figure 3.4-1	+0.03	Flange Bending

Additional Notes

- (1) Margins of Safety for Separation Bolts and Fittings, and the Spacecraft/TLI Adapter, were calculated against Small Sat design loads.
- (2) The Small Sat Booster Adapter was used for this analysis. Other, potentially more efficient designs are under study and are not covered here.



STRUCTURAL TESTING

• Structures & Mechanisms

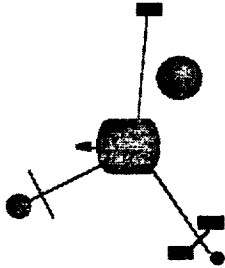
LOCKHEED MARTIN



END ITEM ACCEPTANCE TEST PLAN

TESTING REQUIRED AT SUBCONTRACTOR'S FACILITY

- BUS STRUCTURE
 - MATERIAL COUPON TESTING
 - PROOF TESTING OF STRUCTURE TO 1.15 X LIMIT LOADS
 - DEMONSTRATE WORKMANSHIP AND STRUCTURAL INTEGRITY OF HARDWARE
- MAST
 - MAST DEPLOYMENT
 - PROOF TESTING OF THE SCIENCE INSTRUMENT INTERFACE
 - DEMONSTRATE WORKMANSHIP AND STRUCTURAL INTEGRITY OF HARDWARE



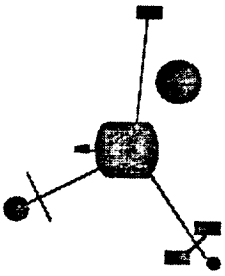
DESIGN

Structures & Mechanisms

LOCKHEED MARTIN

PHSLS

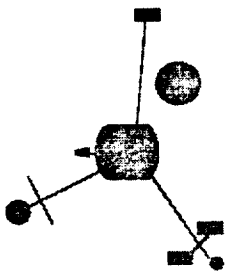
PROGRAM HARDWARE/SOFTWARE LIST (HARDWARE)			TITLE: Structure and Mechanisms Subsystem			Tom Chinn -24356			DATE: 15 Aug 95 REVISION: C PAGE: 1 of 1					
PROGRAM OFFICE APPROVAL:			PROGRAM OFFICE APPROVAL:			STATUS E-EXISTING N-NEW M-MODIFY			CATEGORY D-DEV Q-QUAL R-REL F-FLIGHT S-SPARES			REMARKS		
ITEM #	WBS #	MONOCLATURE	DRAWING NO. /	SPEC NO.	STATUS		BUY	QUANTITY PER CONTRACT				SEC	CLASS	
					DESIGN	HOW		D	Q	R	F			S
2.1.5.1		Solar Drum Panel	P105D211		N	N	S				1		1	DOW UT; Kevlar
2.1.5.2		Equipment Shelf	P105A250		N	N	S				1		1	DOW UT; Gr/Ep
2.1.5.3		Support Module	P105A220		N	N	S				1		1	DOW UT; Gr/Ep
2.1.5.4		Sep Nut Filing	P105D224		N	N	S				1		1	DOW UT; Alum
2.1.5.5		Bolt Catcher	9363739-1		E	N	B				3		3	HI-SHEAR
2.1.5.5		Interface fasteners (SI Interface)	LS42658V08		N	N	B				100		100	LMMS
2.1.5.6		Masts			N	N	S				3		3	ASE ABEL
2.1.5.7		Mast/Boom Support	P105D232		N	N	S				10		10	DOW UT; Gr/Ep
2.1.5.8		Antenna Mast Support	P105D252		N	N	S				1		1	DOW UT; Gr/Ep
2.1.5.9		Mast Release Mechanism	IR1000		N	N	S				1		1	LMMS
2.1.5.10		Floating Inserts (Removable nut element)	SL 6082A		E	N	B				9		9	SHUR-LOCK: similar to (100%)
2.1.5.11		Mast Damper	ISME080		E	N	B				75		75	ASE ABEL
2.1.5.12		Tank Mounting Plate	P105D261		N	N	S				3		3	DOW UT; Alum
2.1.5.13		Tripod Support	P105D262		N	N	S				3		3	DOW UT; Gr/Ep
2.1.5.14		Bearing Support	P105D263		N	N	S				3		3	DOW UT; Alum
2.1.5.15		Thruster Support	P105D264		N	N	S				12		12	DOW UT; Gr/Ep
2.1.5.16		Sun sensor/Limb sensor bracket	P105212		N	N	S				1		1	DOW UT; Gr/Ep
2.1.5.17		Nutation damper support structure	P105D213		N	N	S				1		1	DOW UT; Gr/Ep



MATERIAL FOR EMI/EMC

ASTROSTRIKE SCREEN FOR EMC, ESD PROTECTION

- A HIGH PURITY (99.92%) COPPER FOIL SLIT & EXPANDED TO MAKE A NON-WOVEN SCREEN
- VERY HIGH PURITY/VERY HIGH CONDUCTIVITY
- EXCELLENT SHIELDING PROPERTIES (E-FIELD, H-FIELD, PLANE WAVE
- HIGH CORROSION RESISTANCE (PASSED 3000 HRS SALT SPRAY TEST)
- CAN BE COCURED WITH COMPOSITES: BOND WELL TO EPOXIES/CYANATE-ESTER RESINS



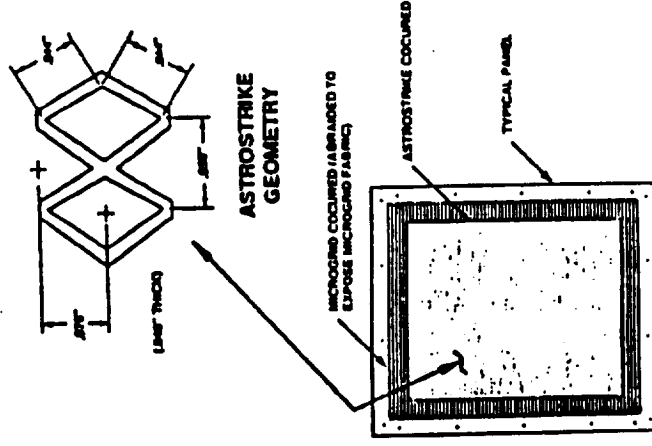
TEST PROGRAM

Structures & Mechanisms

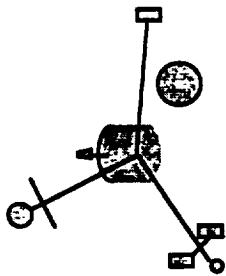
LOCKHEED MARTIN

EMC EFFECTIVENESS

- ASTROSTRIKE/MICROGRID EXPANDED METAL FOIL SELECTED FOR SHIELDING/BONDING
- IMPLEMENTATION RESULTS IN MINIMUM IMPACT TO MANUFACTURING
- MINIMAL 8 LB WEIGHT PENALTY (4% OF TOTAL STRUCTURAL WEIGHT)



TYPICAL PANEL SHIELDING

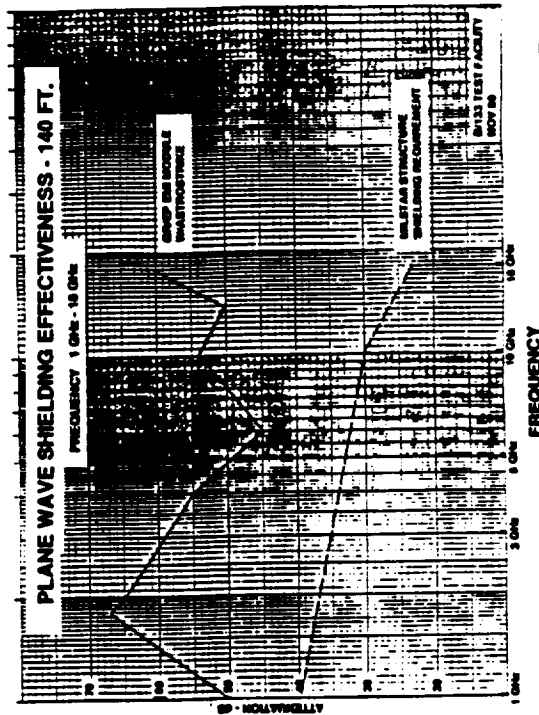
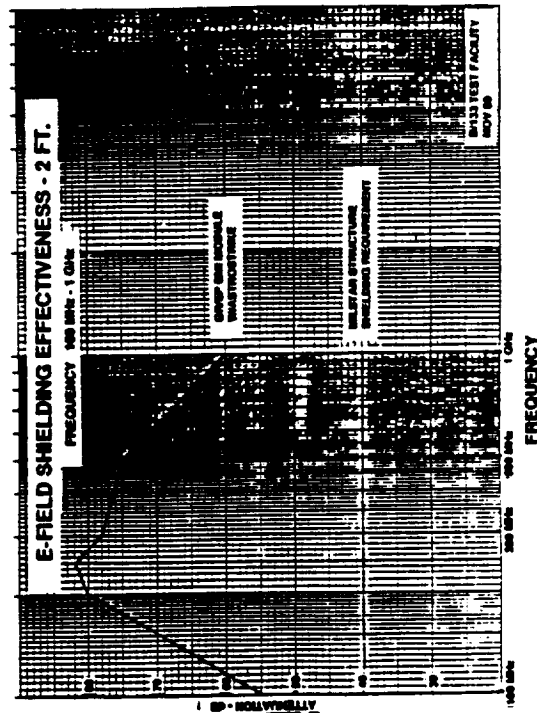
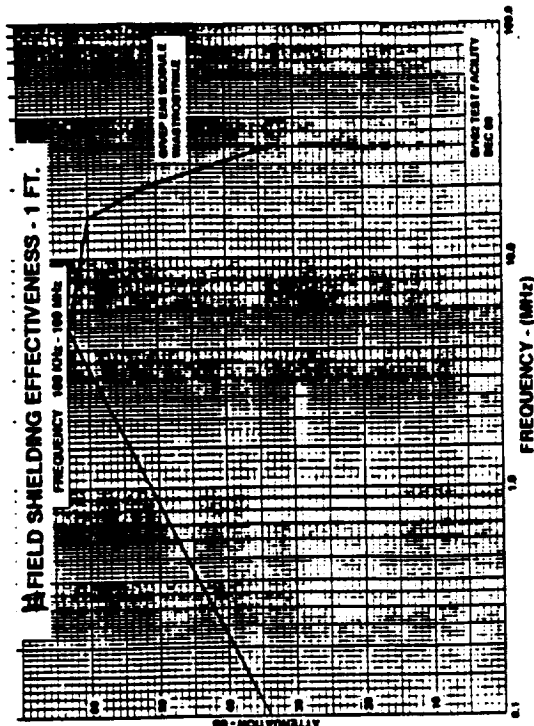
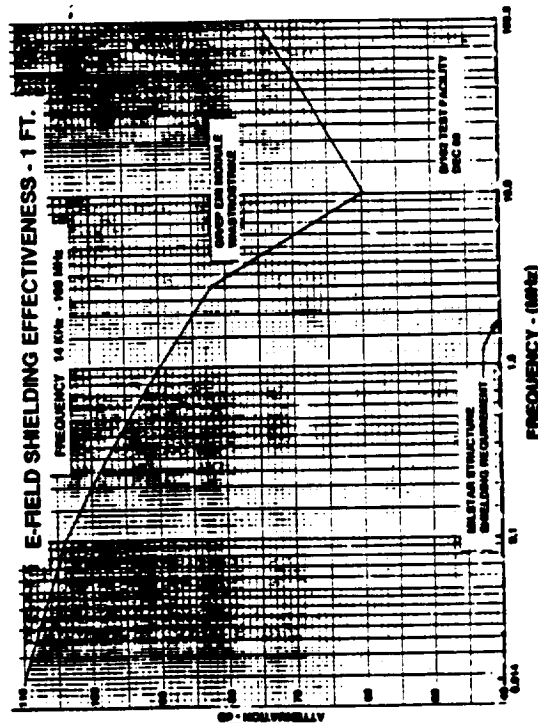


TEST PROGRAM

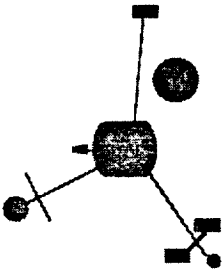
Structures & Mechanisms

EMI SHIELDING EFFECTIVENESS WITH ASTROSTRIKE

LOCKHEED MARTIN



FREQUENCY



Structures & Mechanisms

LOCKHEED MARTIN



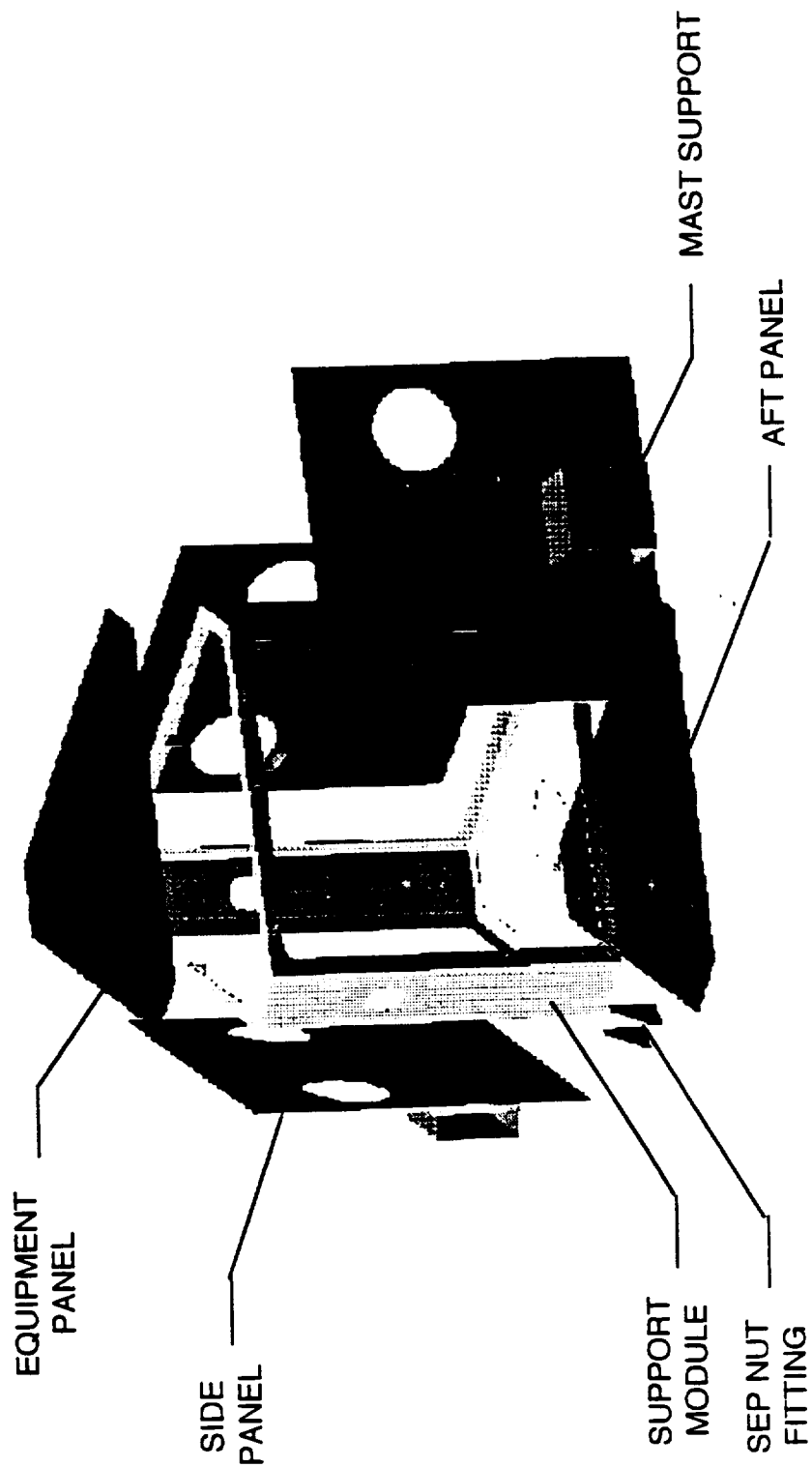
MANUFACTURING

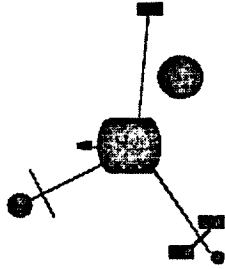
MANUFACTURING

Structures & Mechanisms

LOCKHEED MARTIN

STRUCTURE COMPONENT FABRICATION





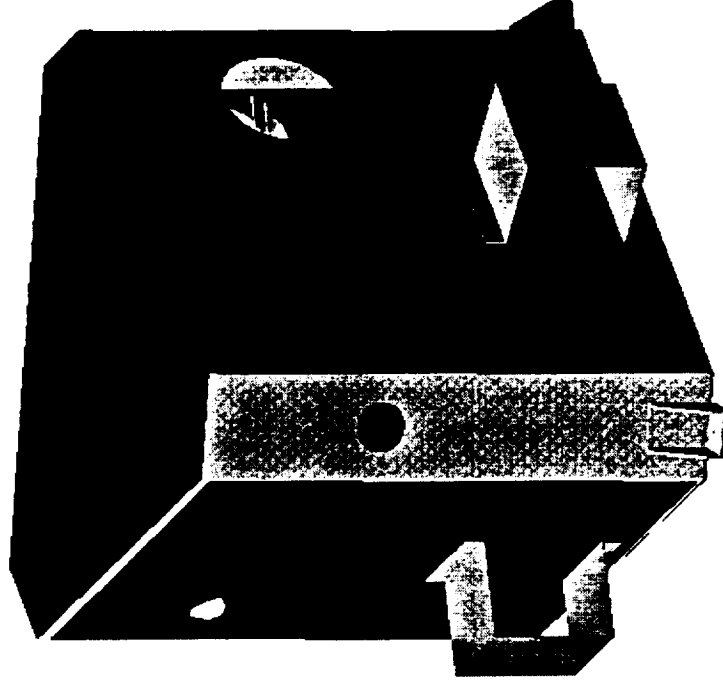
MANUFACTURING

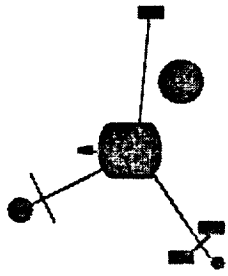
Structures & Mechanisms

LOCKHEED MARTIN



BUS STRUCTURE ASSEMBLY



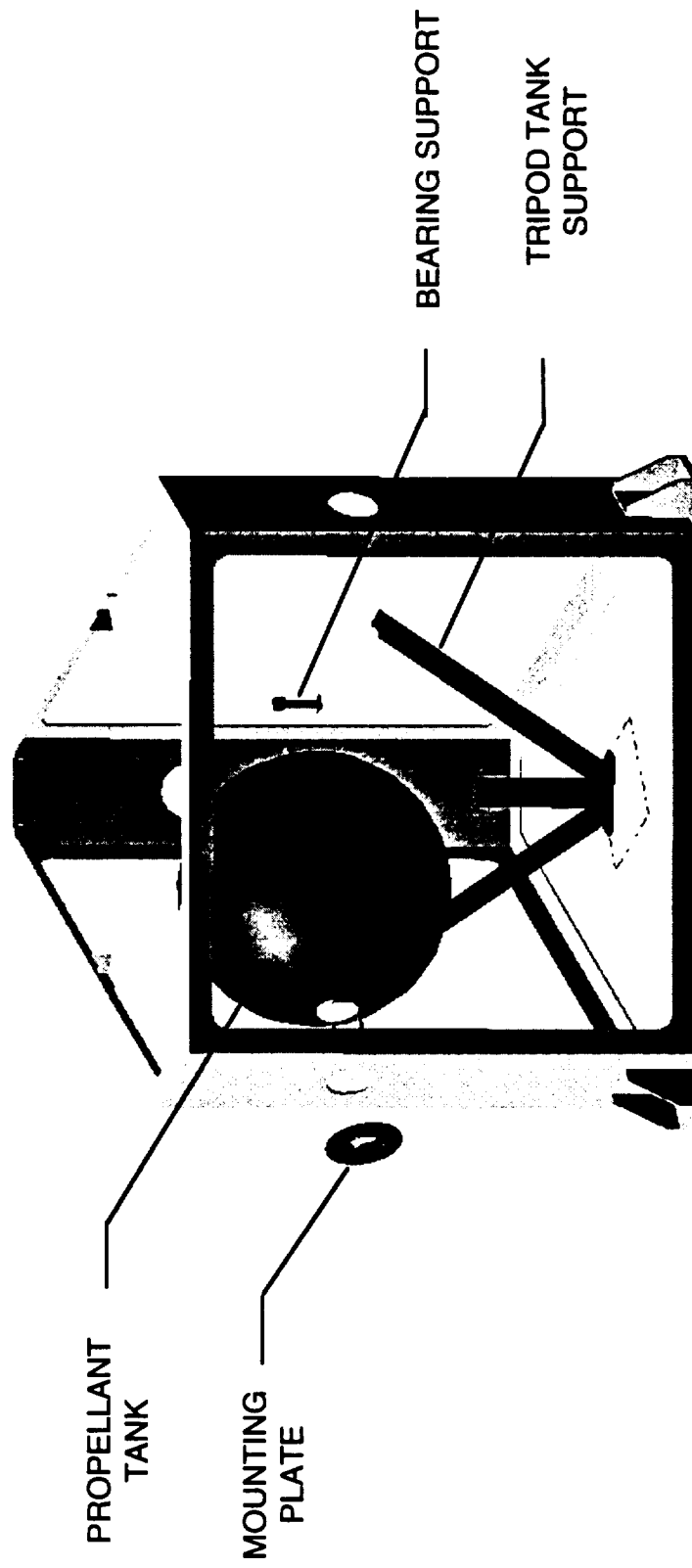


TANK ASSEMBLY

Structures & Mechanisms

LOCKHEED MARTIN

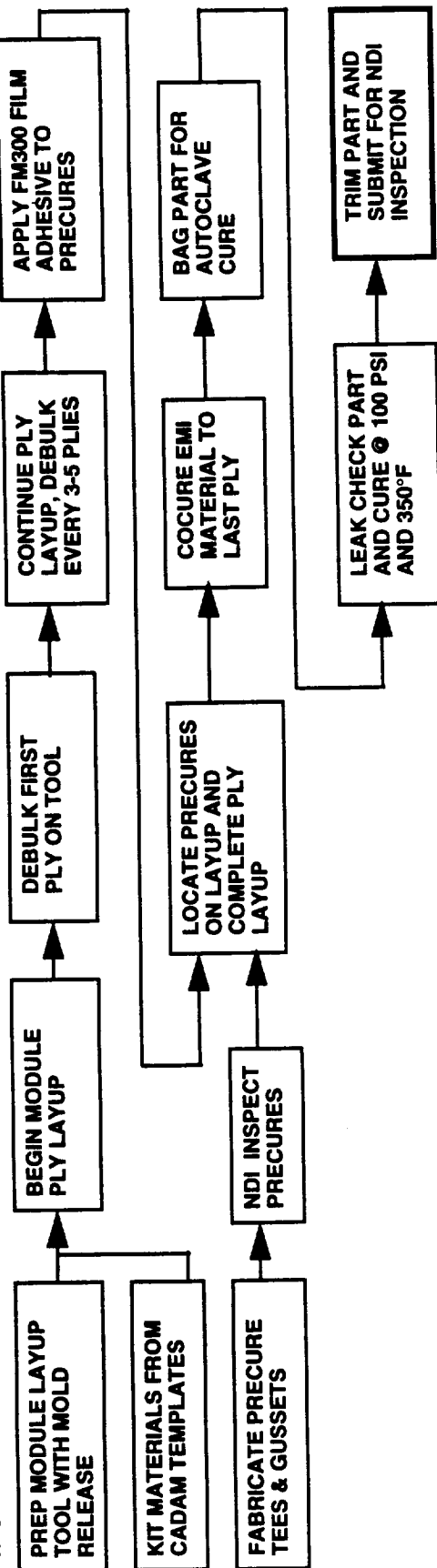
TYPICAL PROPELLANT TANK INSTALLATION



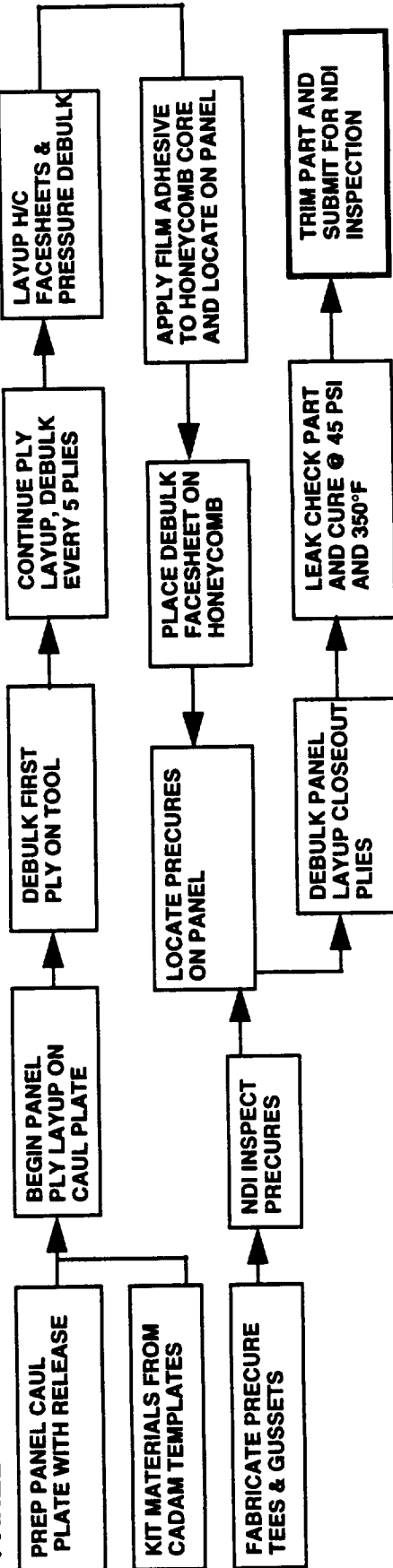


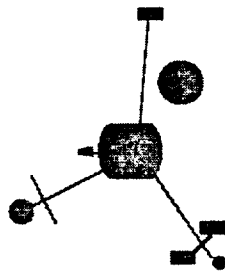
MANUFACTURING PROCESS FLOW PLAN SUPPORT MODULE

MODULE FABRICATION



PANEL FABRICATION



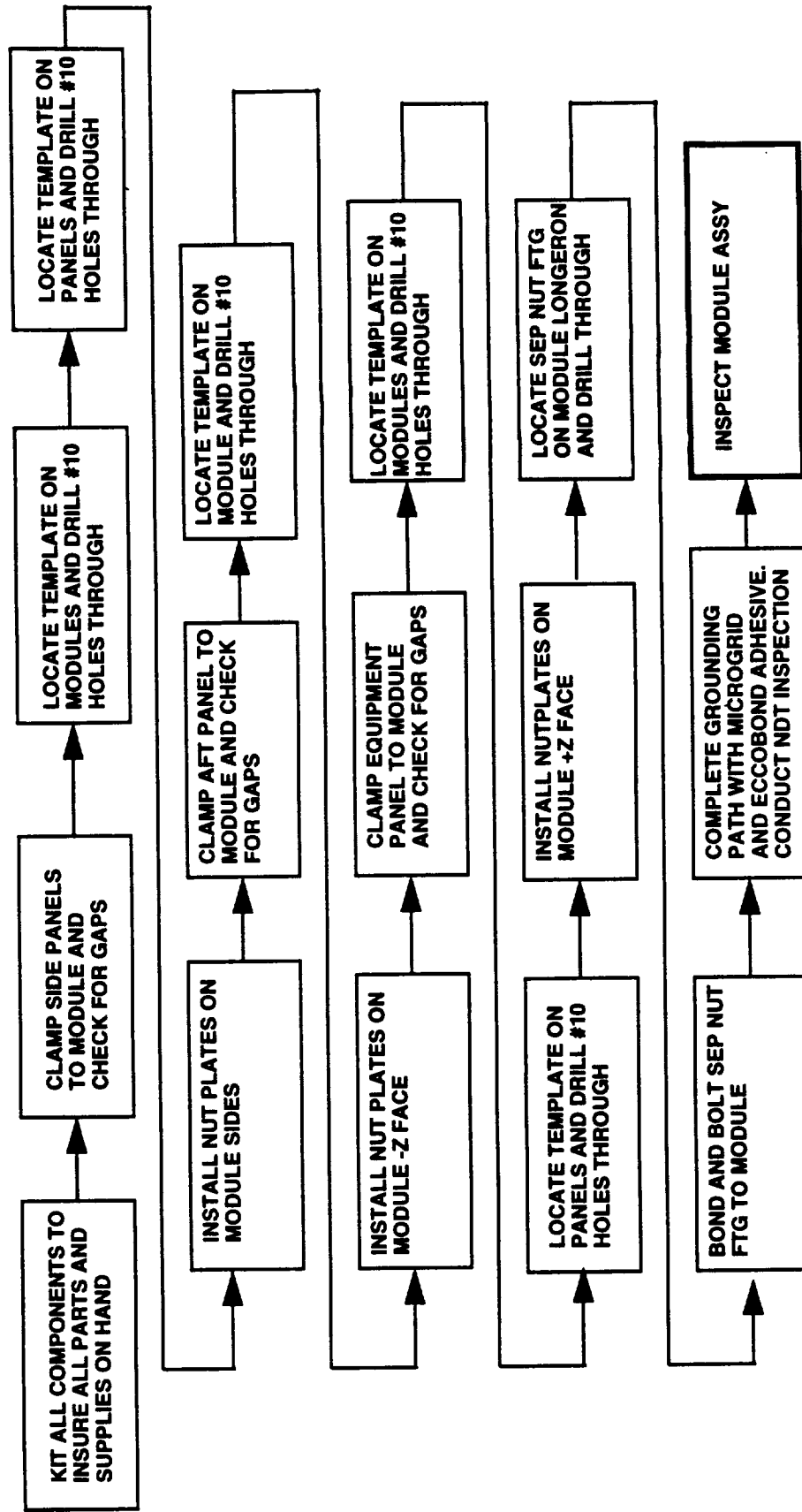


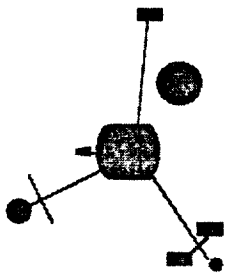
MANUFACTURING

Structures & Mechanisms

LOCKHEED MARTIN

FABRICATION/ASSEMBLY PLAN SUPPORT STRUCTURE



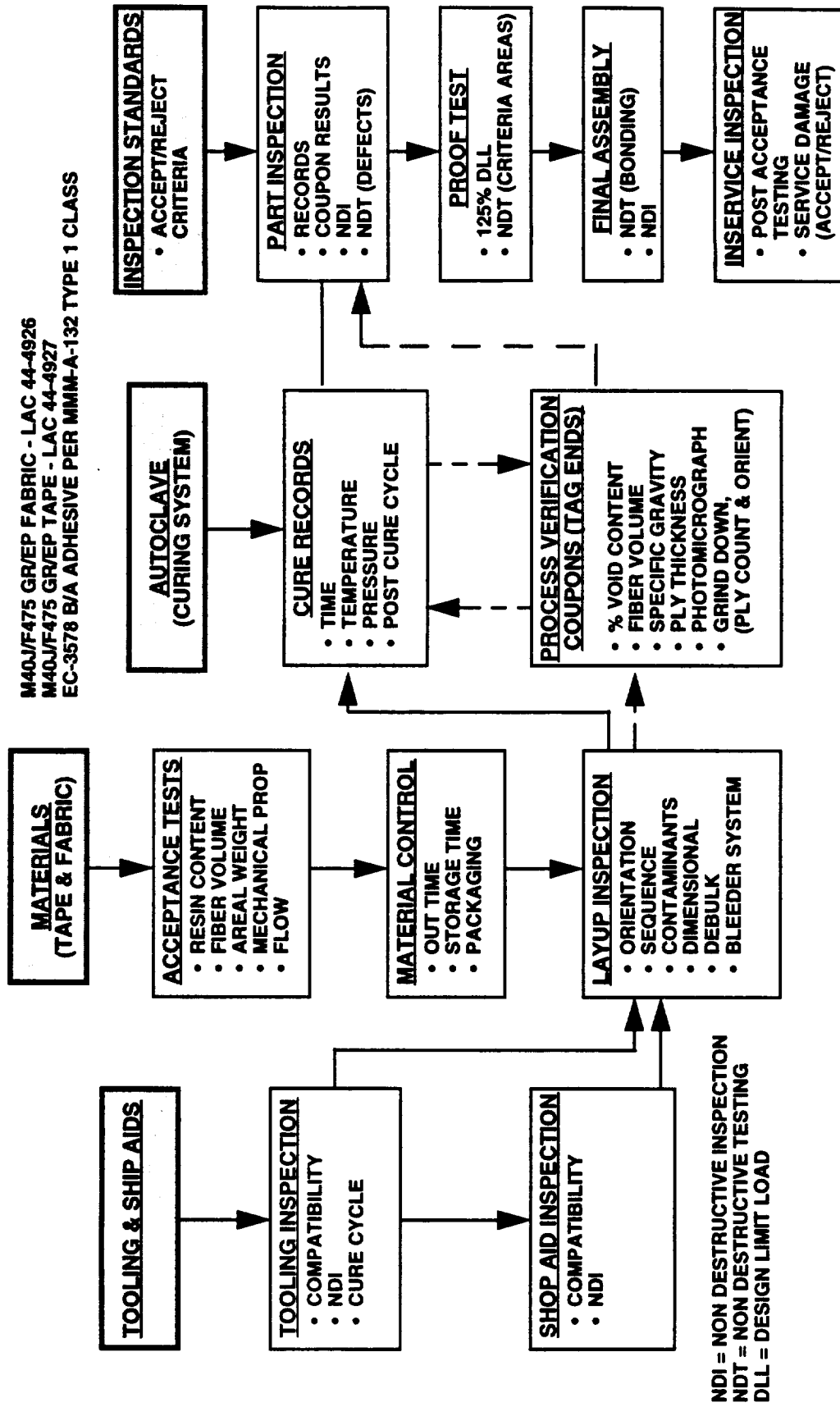


MANUFACTURING

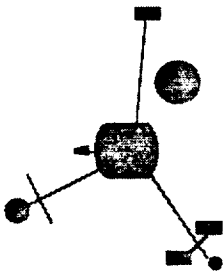
Structures & Mechanisms

LOCKHEED MARTIN

NDT/NDI INSPECTION PLAN



NDI = NON DESTRUCTIVE INSPECTION
NDT = NON DESTRUCTIVE TESTING
DLL = DESIGN LIMIT LOAD



MANUFACTURING

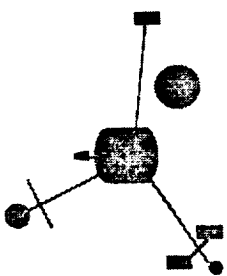
- Structures & Mechanisms

LOCKHEED MARTIN

REPAIRABILITY

REPAIRABILITY OF ADVANCE COMPOSITE STRUCTURES

- REPAIR MUST RESTORE CAPABILITY OF THE PART TO WITHSTAND DESIGN ULTIMATE LOADS AND FULL SERVICE LIFE OF THE PART
- TWO BASIC TYPES OF REPAIR
 - BOLTED REPAIRS
 - COMPARABLE TO METAL REPAIRS.
 - REQUIRES NO SPECIALIZED EQUIP.
 - CARE IN DRILLING REQUIRED.
 - ADDITIONAL CUTOUTS STRUCTUALLY UNDESIRABLE.
 - BONDED REPAIRS
 - REQUIRES SPECIALIZED SKILLS AND EQUIP.
 - CURE-IN-PLACE REPAIRS.
 - STRUCTURAL ADVANTAGES SINCE NO CUTOUT OR DRILLING REQUIRED.



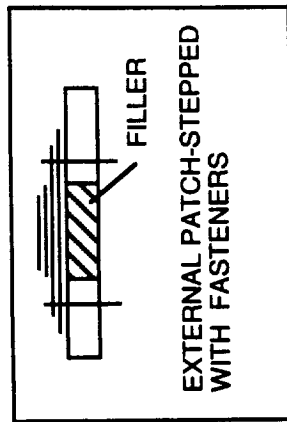
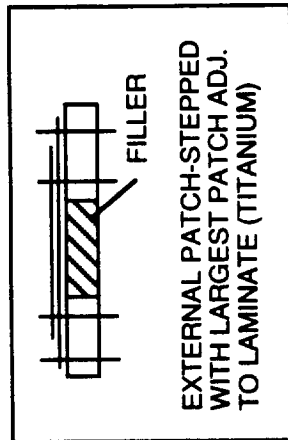
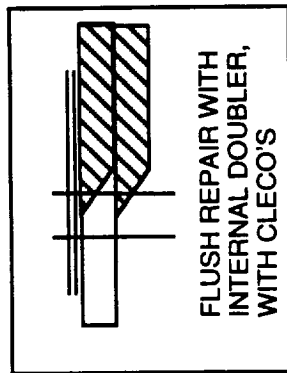
MANUFACTURING

Structures & Mechanisms

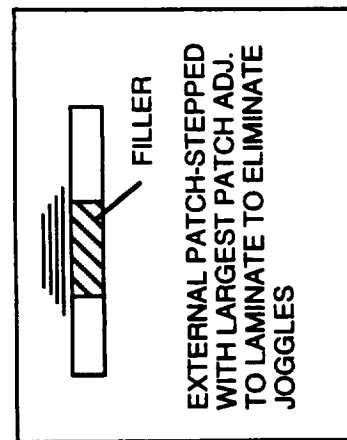
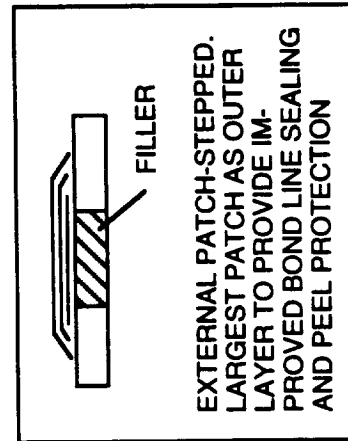
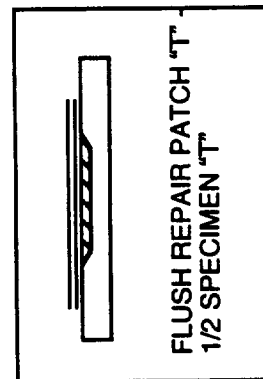
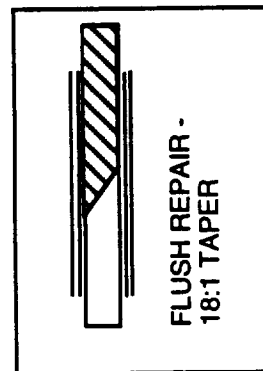
LOCKHEED MARTIN

POSSIBLE REPAIR CONFIGURATIONS

• BOLTED REPAIRS



• BONDED REPAIRS

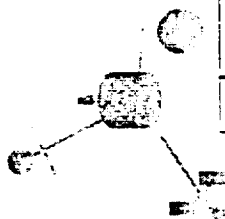


TYPE 1

TYPE 2

TYPE 3

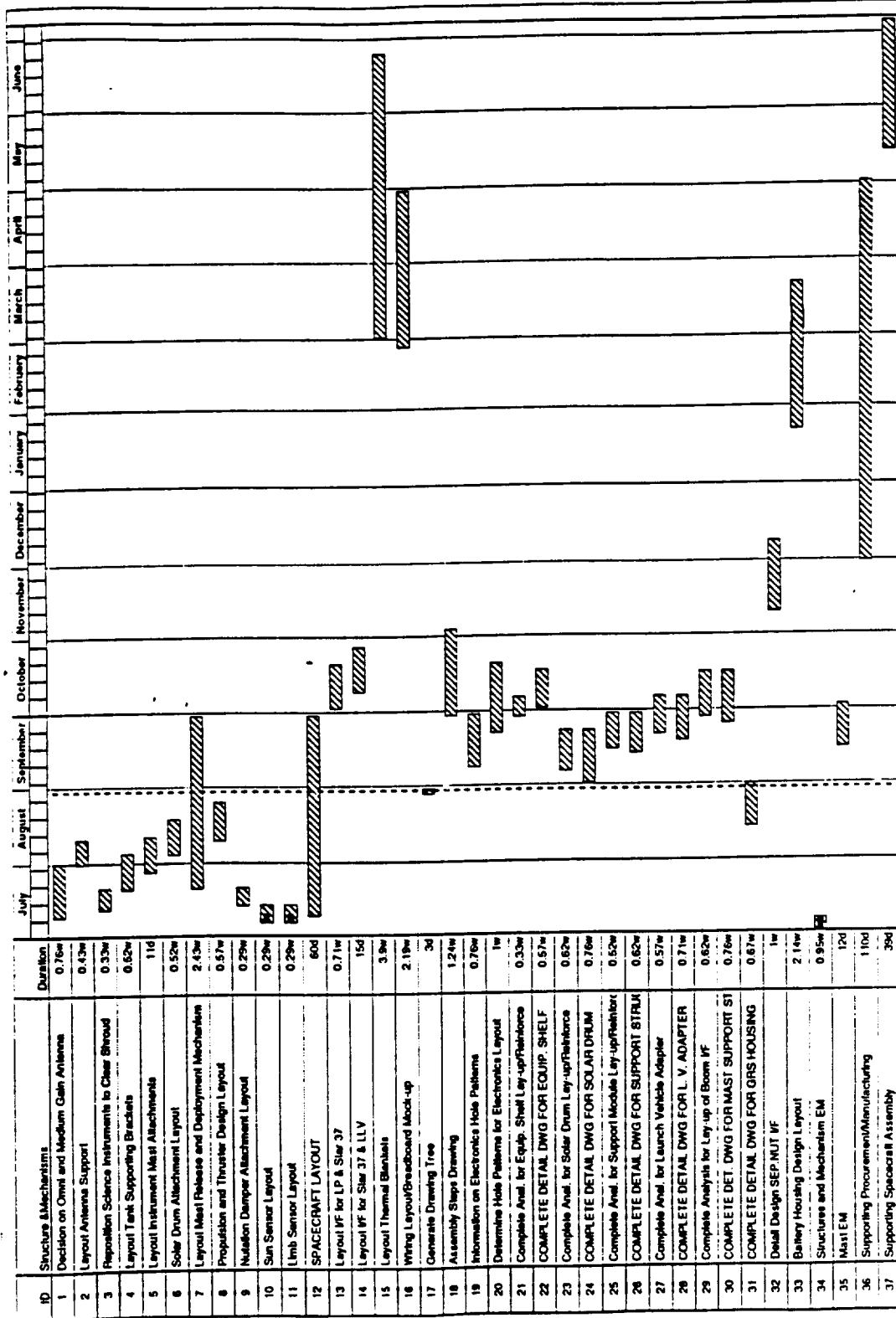
TYPE 4



SCHEDULE

LOCKHEED MARTIN

Structures & Mechanisms



Project
Date 9/30/95

Critical

Noncritical

Progress

Milestone

Summary

Roll Up

SUMMARY & ISSUES

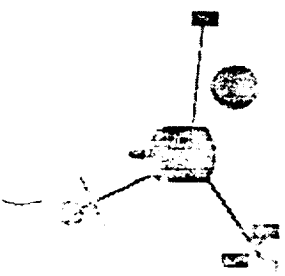
Structures & Mechanisms

LOCKHEED MARTIN

- Lunar Prospector primary spacecraft structure design is nearly complete
- Design drawings and tooling are in place for fabrication of module structure
- Launch lock concept & release mechanisms required for the Science Instruments



Mechanism

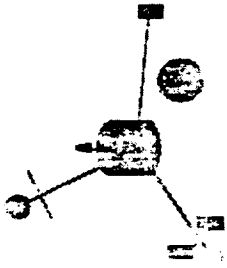


■ Structures & Mechanisms

LOCKHEED MARTIN



Science Instruments Deployment Mechanism



S. I. Deployment Mechanism

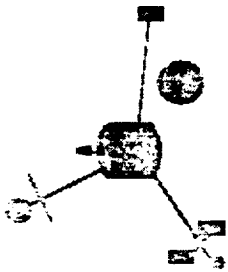
Structures & Mechanisms

LOCKHEED MARTIN



REQUIREMENTS:

- Deploy Science Instrument Assemblies 2.5 m from the Spacecraft
- Controllable deployment rate (≤ 2.54 cm/min) *See*
- Support total tip mass of 7.2 Kg
- Deployment force margin > 1.0



S. I. Deployment Mechanism

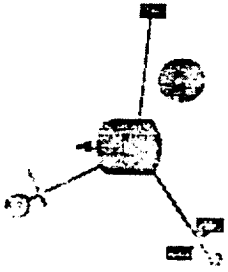
— Structures & Mechanisms

LOCKHEED MARTIN



PHYSICAL CHARACTERISTICS

- Length: 2.5 m
- Deployment rate: 2.54 cm/sec
- Mast diameter: 20.1 cm
- Deploy force: 7.63 lbs
- Stiffness
 - Bending (EI): 1.54E+06 lb-in²
 - Shear (GA): 3.00E+03 lb
 - Torsion (GJ): 1.94E+04 lb-in²
 - Axial (AE): 2.20E+05 lb



S. I. Deployment Mechanism

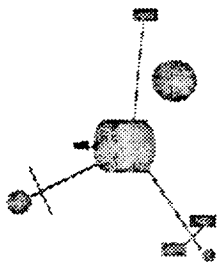
Structures & Mechanisms

LOCKHEED MARTIN



BOOM ANALYSIS RESULTS:

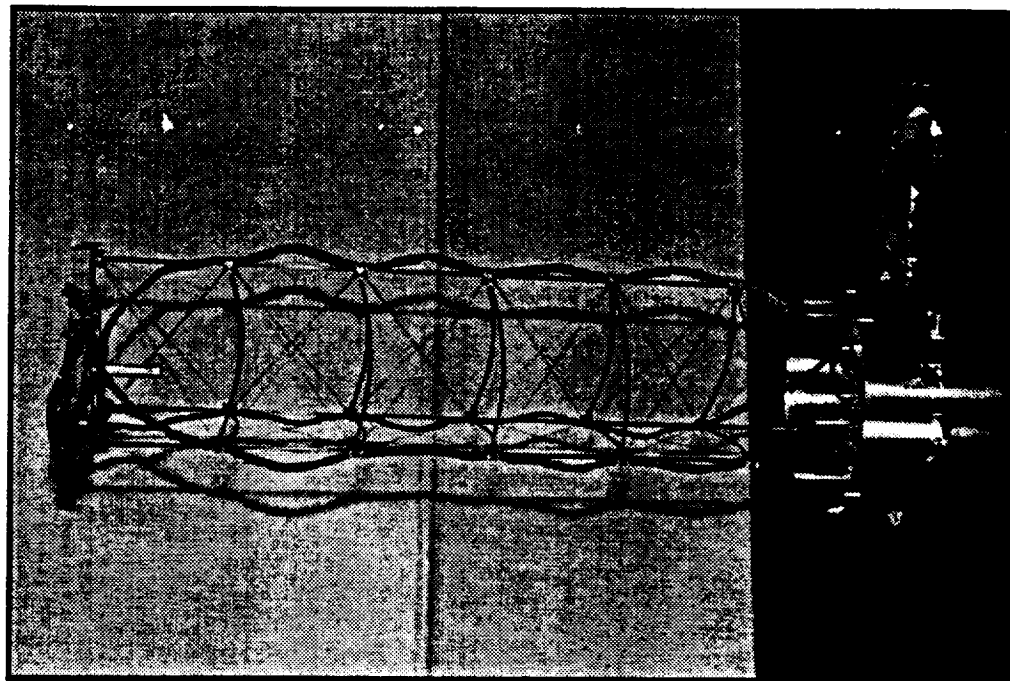
- Bending capability - 20.52 N.m
- Bending due to:
 - Orbit adjust - 11.34 N.m
 - Spin make-up - 15.8 N.m
 - Coriolis - $< 0.10^\circ$ (during deployment)

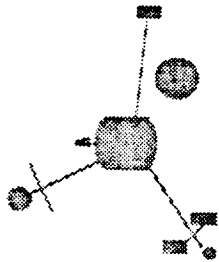


Mast Deployed Configuration

— Structures & Mechanisms

LOCKHEED MARTIN

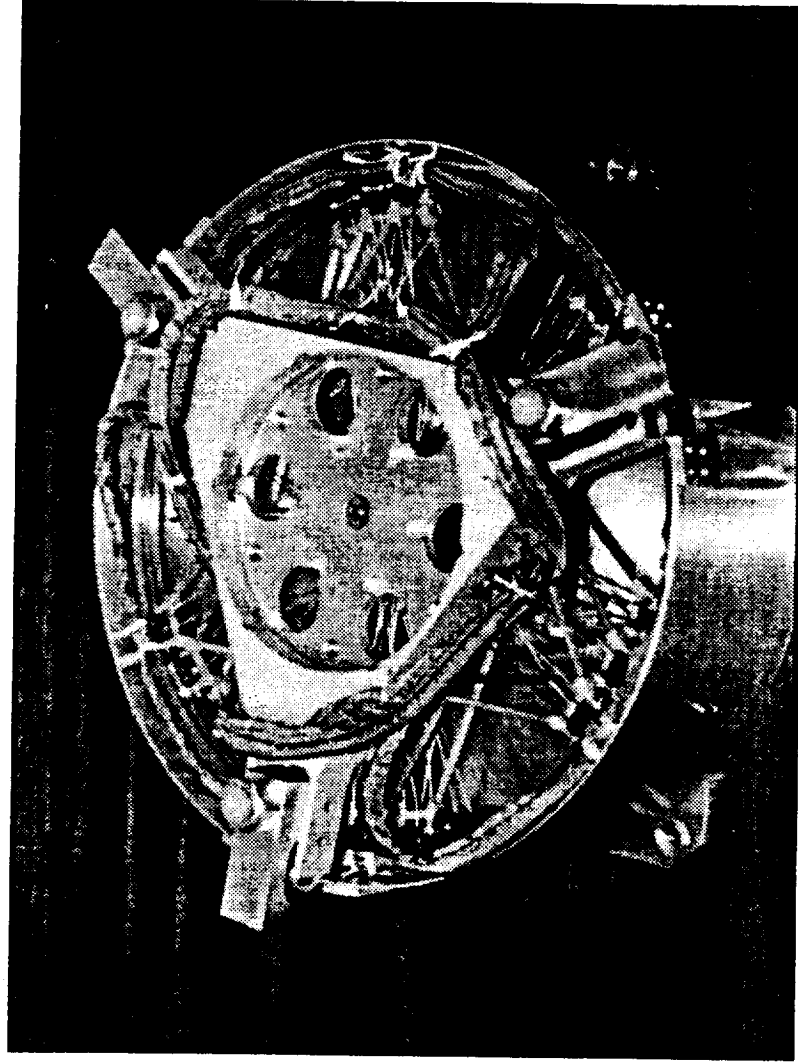




Mast Stowed Configuration

Structures & Mechanisms

LOCKHEED MARTIN

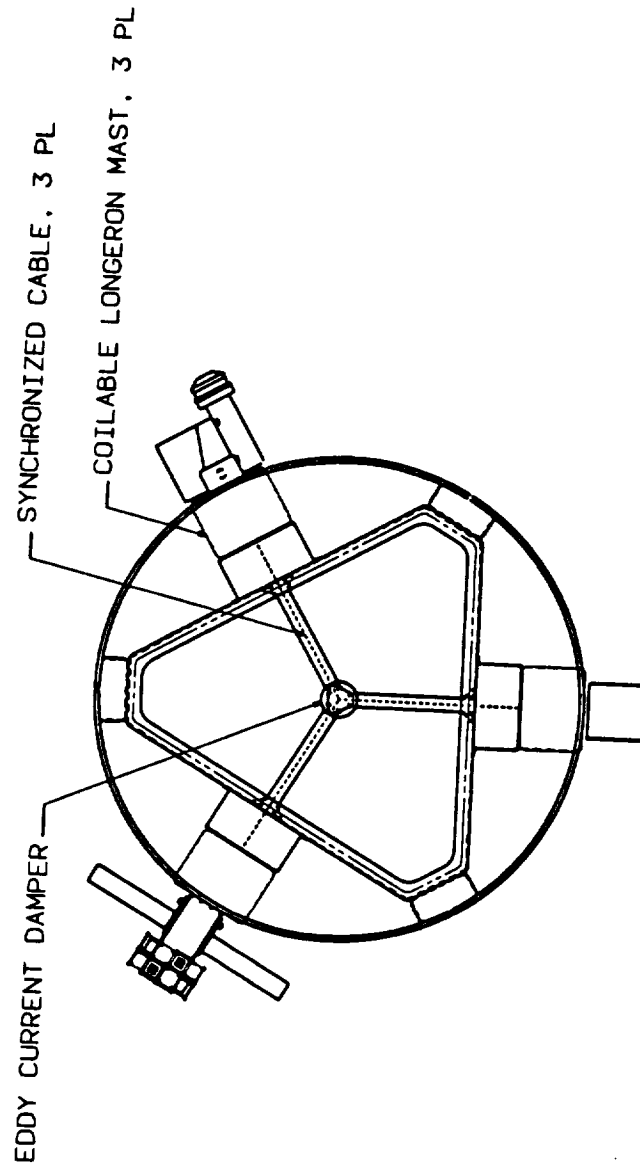


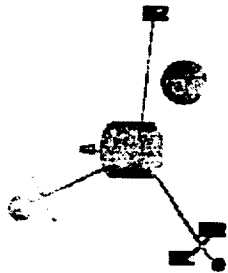


Synchronized Deployment Mechanism

Structures & Mechanisms

LOCKHEED MARTIN

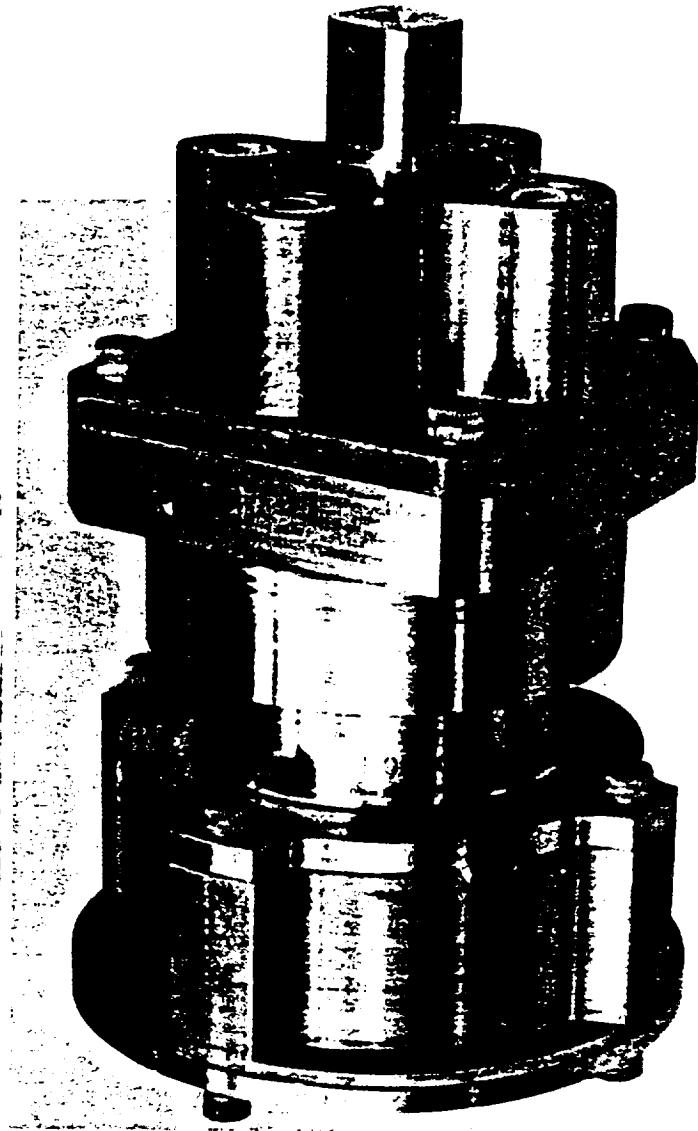




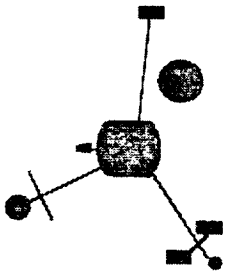
Eddy Current Rotary Damper

Structures & Mechanisms

LOCKHEED MARTIN



EDDY CURRENT ROTARY DAMPER PART NO.	2980946-1
DAMPING RATES (IN-LB-SEC/RAD)	10,000 TO 20,000
DAMPING TORQUE CAPABILITY (IN-LB)	700 (MAX.)
ROTATIONAL RANGE	CONTINUOUS
TOTAL WEIGHT (LBS.)	1.55
QUALIFICATION TEMPERATURES (°F)	- 60° / + 220°
FLIGHT HERITAGE	MILSTAR



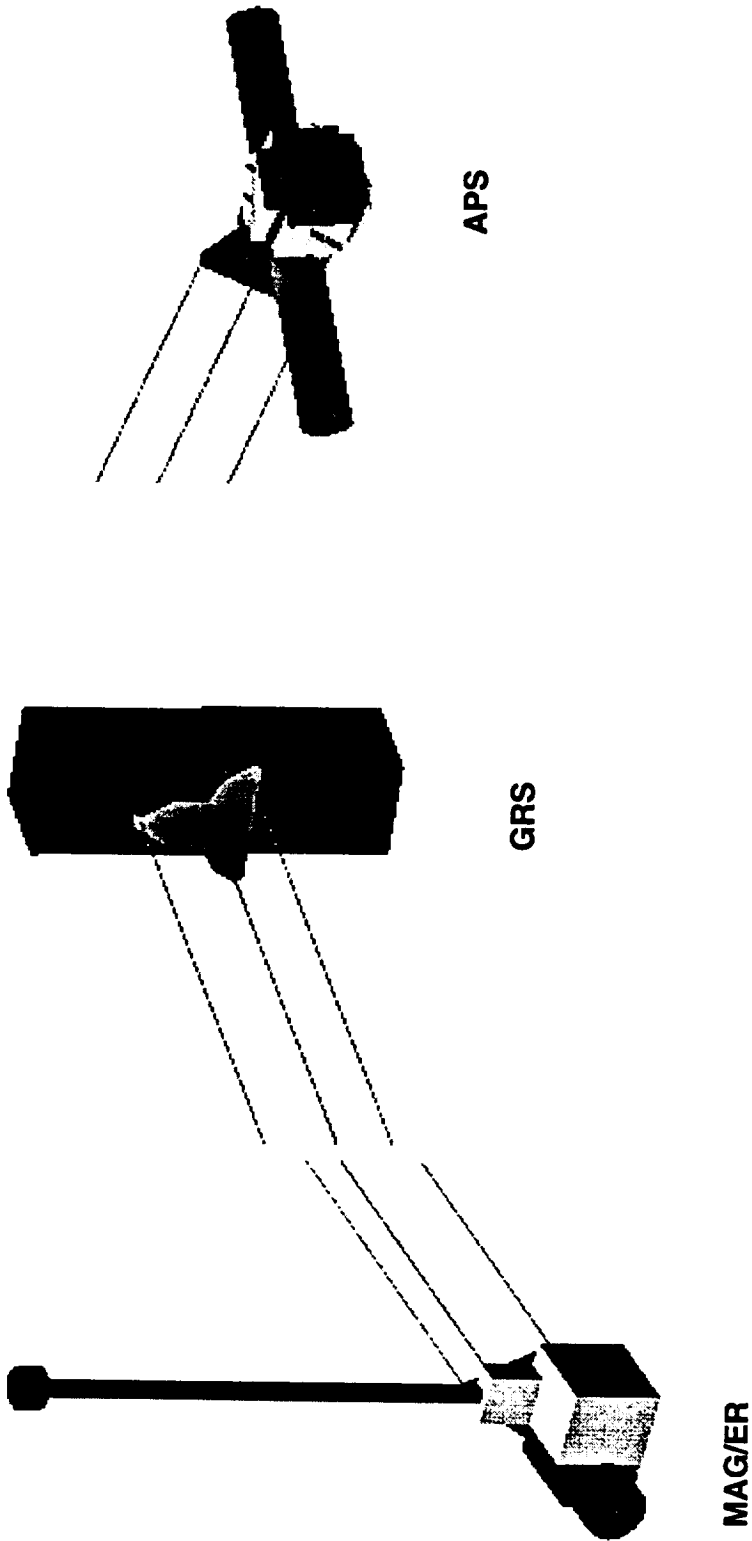
DESIGN

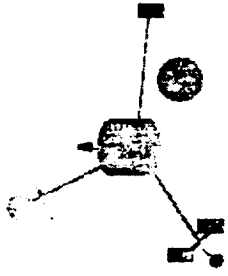
Structures & Mechanisms

LOCKHEED MARTIN



SCIENCE INSTRUMENT SPACECRAFT INTERFACE



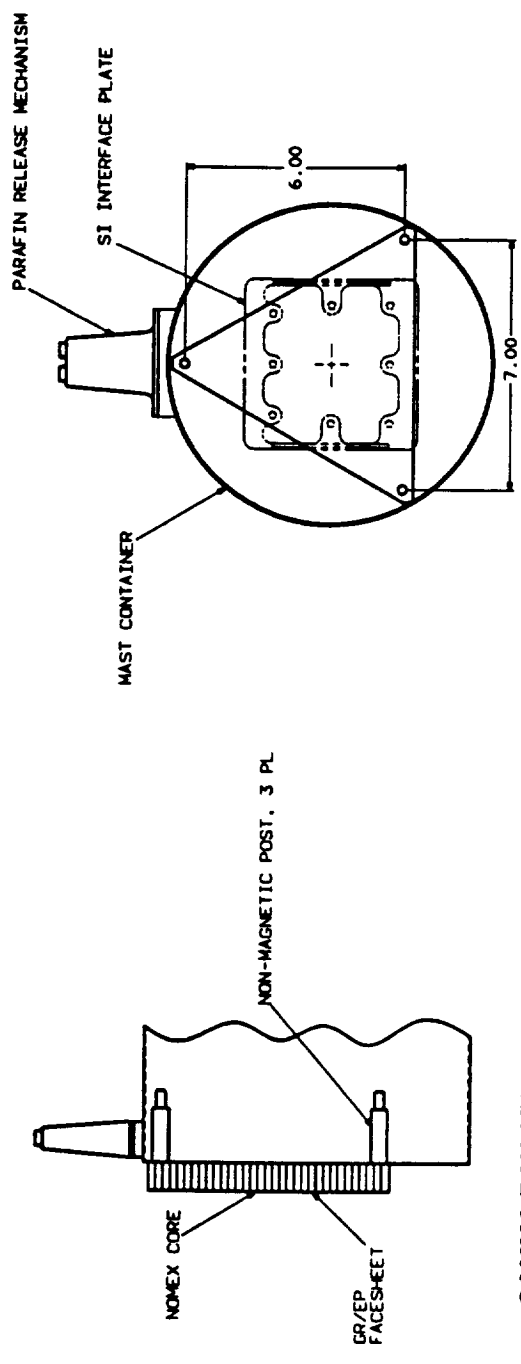


Science Instruments Interface

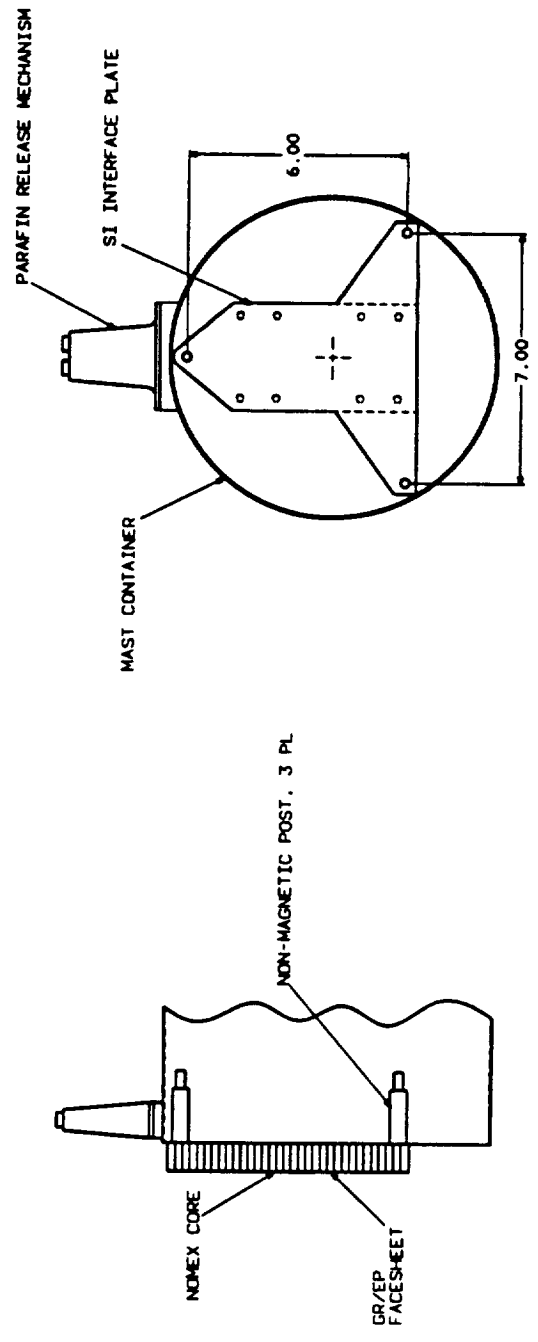
Structures & Mechanisms

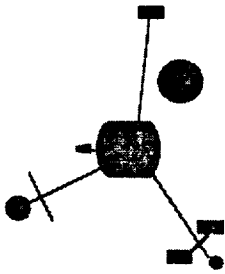
LOCKHEED MARTIN

ALPHA PARTICLE & NEUTRON SPECTROMETER AND MAGNETOMETER & ELECTRON SPECTROMETER



GAMMA RAY SPECTROMETER





■ Structures & Mechanisms

LOCKHEED MARTIN

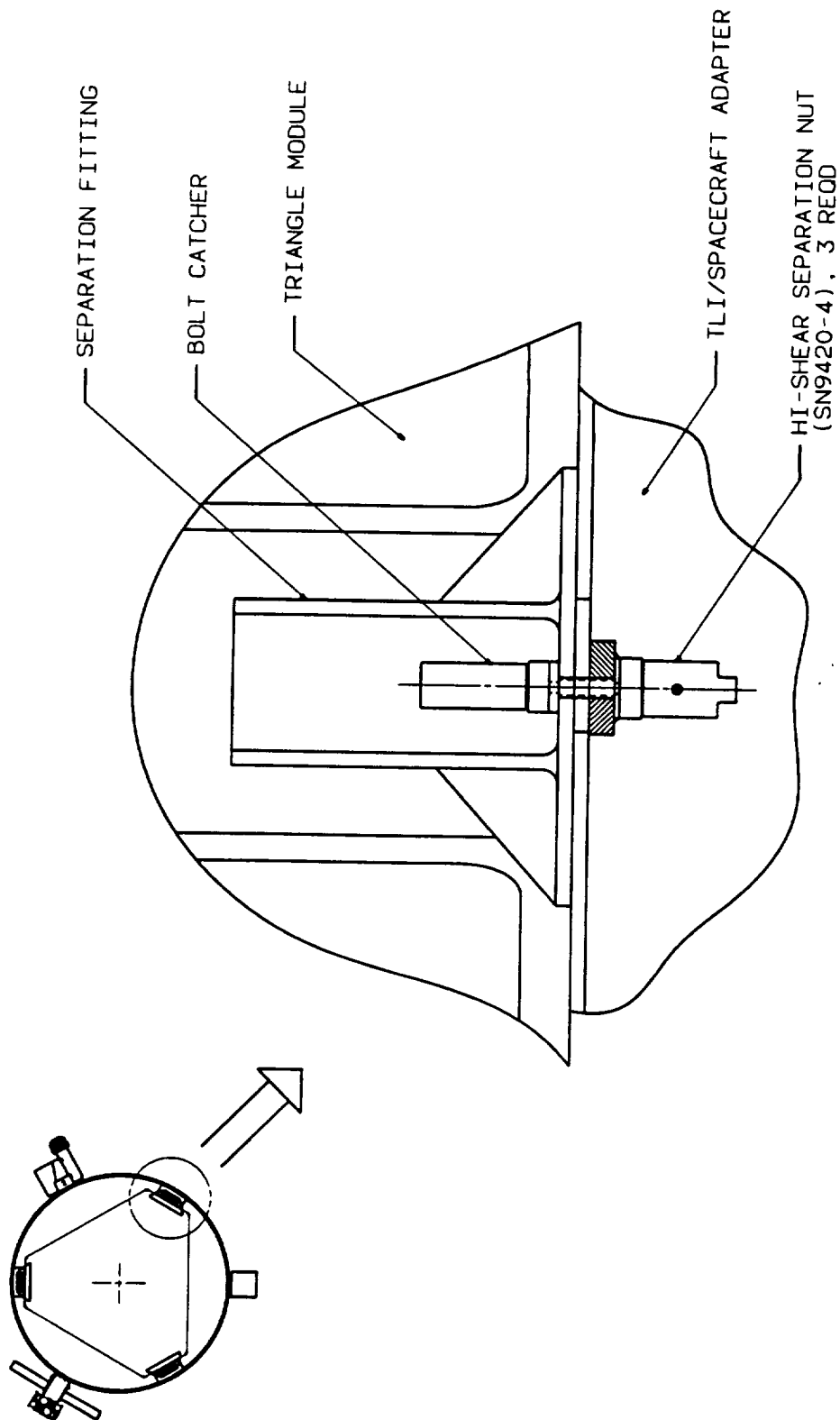


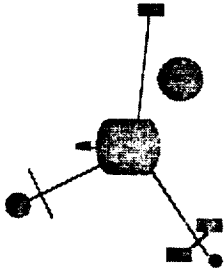
TLI/Spacecraft Separation System

TLI/Spacecraft Separation

Structures & Mechanisms

LOCKHEED MARTIN





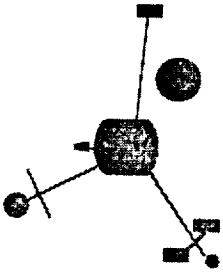
General Feature Description

— Structures & Mechanisms

LOCKHEED MARTIN



- Manufacturer: Hi - Shear
- Low Shock Output
- Ultra-fast Release
- Completely Gas & Particle Containing
- Light weight (comparing to Marman clamp system)
- Tensile load: 23,400 lbs
- 1/2 Separation Nut used on Viking Lander, CRSS & Iridium



Separation Analysis

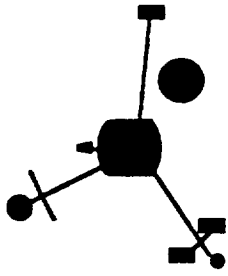
— Structures & Mechanisms —

LOCKHEED MARTIN 

- Compatible with the Triangle module
- Performance is comparable with the Marman clamp system
- Separation velocity : 0.3048 m/sec approximately
- Tip - off rate : 0.6 degree/sec
- Half cone angle: 0.2 degree

FUTURE SEPARATION ANALYSIS:

- Fluid propellant sloshing
- “Hung corner” dynamics



Thermal Control

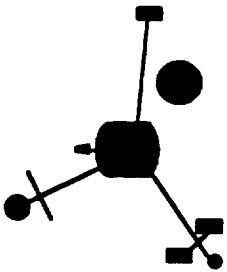
LOCKHEED MARTIN



Thermal Control Subsystem

Jim Schirle

Page 1
JRS 9/6/95



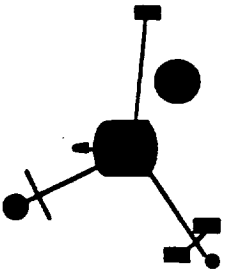
Thermal Control

TCS Functions

LOCKHEED MARTIN



The Thermal Control Subsystem (TCS) maintains all spacecraft subsystems within their required thermal limits during all phase of the mission



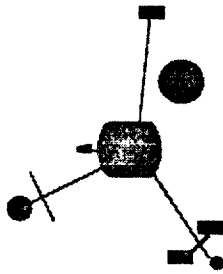
Key TCS Requirements

■ Thermal Control

LOCKHEED MARTIN



- 1 year design life
- 3 year life for extended mission with reduced temperature margins
- Solar vector $\pm 35^\circ$ from normal to spin axis for translunar phase
- Solar vector $\pm 5^\circ$ from normal to spin axis for lunar orbit
- Re-orientation maneuvers and duration 3 hours maximum
- Worst case lunar occultation of 47 minutes at 100 km
- 100 km lunar orbit
- 118 minute lunar orbit period with up to 47 minute eclipse
- Daily average TCS power less than 15 watts
- Fully redundant bus heater circuits



SI Temperature Requirements

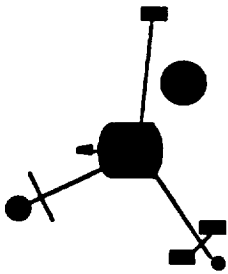
Thermal Control

LOCKHEED MARTIN



Component	Temperature Requirements (°C)	
	Operate	Survival
Gamma Ray Spectrometer	-45 to -35°C*	-45 to 45°C
Neutron Spectrometer	-20 to 10°C	-25 to 45°C
Alpha Particle Spectrometer	-20 to 10°C	-25 to 45°C
Spectrometer Electronics	-25 to 40°C	-40 to 50°C
Magnetometer	-20 to 45°C	-20 to 45°C
Electron Reflectometer	-15 to 45°C	-30 to 45°C
Mag/ER Electronics	-10 to 40°C	-20 to 40°C

* Maximum lunar orbital temperature swing less than 2°C in 118 minutes



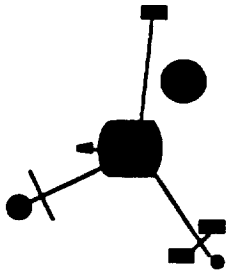
SI Power Dissipations

Thermal Control

LOCKHEED MARTIN



Component	Thermal Power Dissipation (watts)	
	Operate	Standby
Gamma Ray Spectrometer	0.08	0.05
Neutron Spectrometer	0.1	0.1
Alpha Particle Spectrometer	0.6	0.6
Spectrometer Electronics	11.4	11.4
Magnetometer	0.06	0.06
Electron Reflectometer	2.0	1.5
Mag/ER Electronics	2.5	2.5

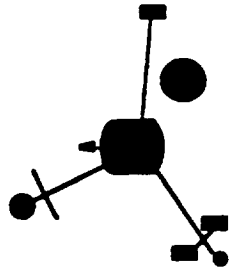


Component Temperature Limits (°C)

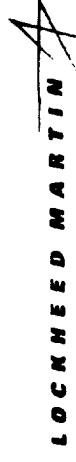
Thermal Control

LOCKHEED MARTIN

COMPONENT	Protoqual		ATP/Operate Temperature (°C)		Survival Temperature (°C)	
	Min	Max	Min	Max	Min	Max
Transponder	-35	60	-30	55	-40	65
Medium Gain Antenna	-105	71	-100	66	-111	77
Low Gain Antenna	-105	71	-100	66	-111	77
Switching and Routing Elec	-35	60	-30	55	-40	65
C&DH Electronics	-35	60	-30	55	-40	65
Sun Sensor	-55	65	-50	60	-65	70
Limb Crossing Sensor	-55	65	-50	60	-65	70
Nutation Damper	-35	60	-30	55	-40	65
Booms	-60	60	-55	55	-200	60
Release Mechanisms	-55	65	-50	60	-65	70
Eddy Current Damper	-60	160	-55	155	-60	160
Solar Array Panel Assembly	-85	85	-80	80	-120	130
NiCad Battery	n/a	n/a	-4	25	-10	30
Power Control Assembly	-35	60	-30	55	-40	60
Propulsion Components	4	49	4	49	4	49

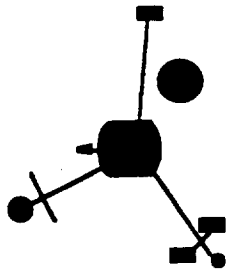


Thermal Environments



■ Thermal Control

- Storage
- Transportation
- Prelaunch
- Ascent
- Earth orbit
- Translunar trajectory
- Lunar Orbit



Thermal Environments

Thermal Control

LOCKHEED MARTIN



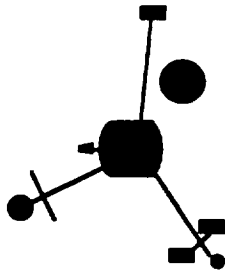
Transportation and Storage During storage and transportation the environment surrounding the vehicle is controlled to the following:

- a. Cleanliness: Fed Std. 209, Class 300,000, or better.
- b. Temperature: $21^{\circ}\text{C} \pm 8^{\circ}\text{C}$ with short excursions (less than 12 hours) to $21^{\circ}\text{C} \pm 17^{\circ}\text{C}$.
- c. Relative Humidity: 20% to 60% with no condensation permitted.

Pre-launch and Ground Testing During prelaunch operations and ground testing, the environment surrounding the vehicle is controlled to the following:

- a. Cleanliness: Visibly clean
- b. Temperature: $21^{\circ}\text{C} \pm 8^{\circ}\text{C}$ with short excursions (less than 12 hours) to $21^{\circ}\text{C} \pm 17^{\circ}\text{C}$.
- c. Relative Humidity: 20% to 60% with no condensation permitted

Non-operational Flight Modes During launch, ascent, and initial S/C deployment SI component housing temperatures are maintained within survival limits



Environmental Constants

Thermal Control

LOCKHEED MARTIN

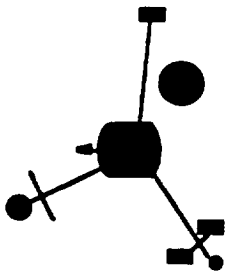


Earth Orbit Environmental Constants

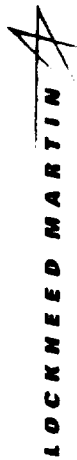
	Cold	Nominal	Hot
Direct Solar	1323 w/m2	1368 w/m2	1414 w/m2
Albedo	0.25	0.30	0.35
Planetary IR	223 w/m2	226 w/m2	237 w/m2

Lunar Orbit Environmental Constants

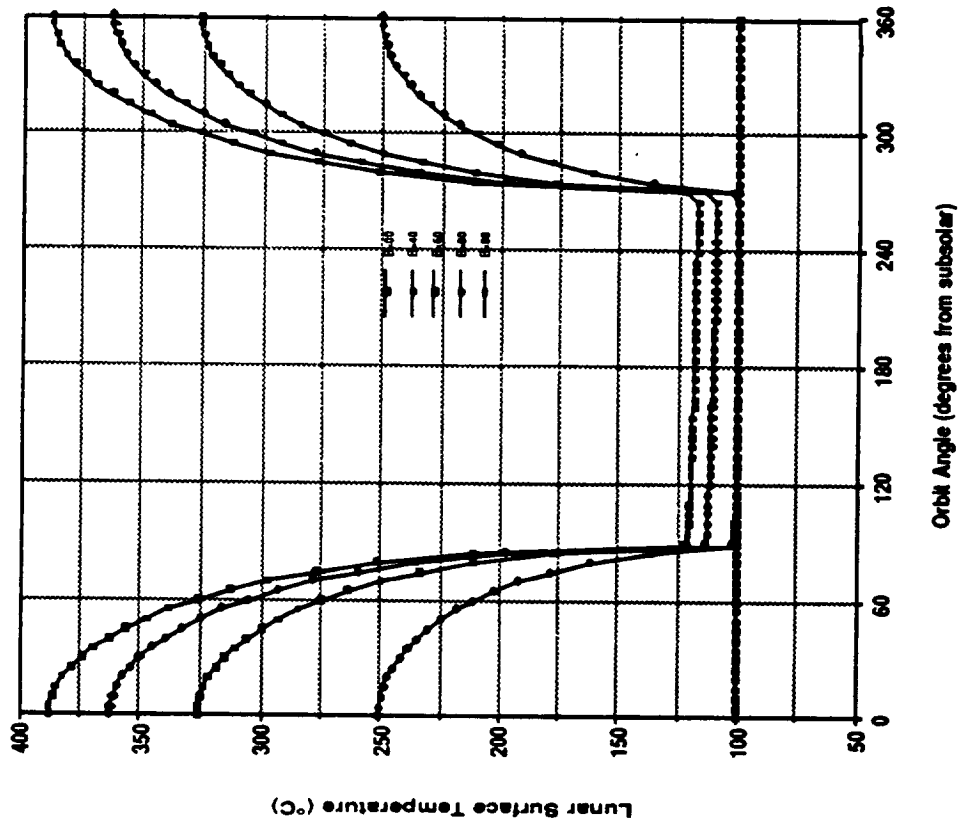
	Cold	Nominal	Hot
Direct Solar	1323 w/m2	1368 w/m2	1414 w/m2
Albedo	0.073	0.073	0.073
Planetary IR - Min	1226 w/m2	1268 w/m2	1314 w/m2
- Max	5.2 w/m2	5.2 w/m2	5.2 w/m2

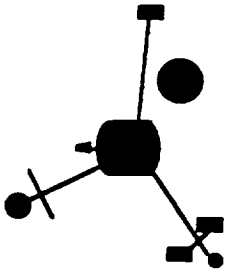


Moonshine Model



Thermal Control



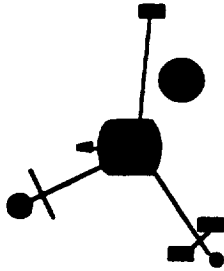


Thermal Design Cases

LOCKHEED MARTIN

Thermal Control

- Earth orbit (12 cases)
 - 185 km circular orbit
 - Solar, albedo, and planetshine (hot and cold constants)
 - BOL surface finishes
 - Sun -35° , 0° , and $+35^\circ$ from normal to spin axis
 - Orbit beta angles = 0° , 90°
 - 38 minute eclipse
- Translunar Orbit (10 cases)
 - Solar only (hot and cold solar constants)
 - BOL surface finish properties
 - Sun -35° , 0° , and $+35^\circ$ from normal to spin axis
 - 3 hour re-orientation maneuver; sun on $\pm Z$ (no solar on sides)
- Lunar Orbit (25 cases)
 - 100 km circular orbit
 - Solar, albedo, and planetshine (hot and cold constants)
 - BOL and 1 year surface finish properties
 - Sun -5° and $+5^\circ$ from normal to spin axis
 - Orbit beta angles = 0° , 72° , and 90° (TBR)
 - 47 minute occultation



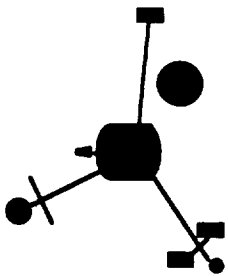
Extended Mission Cases

Thermal Control

LOCKHEED MARTIN



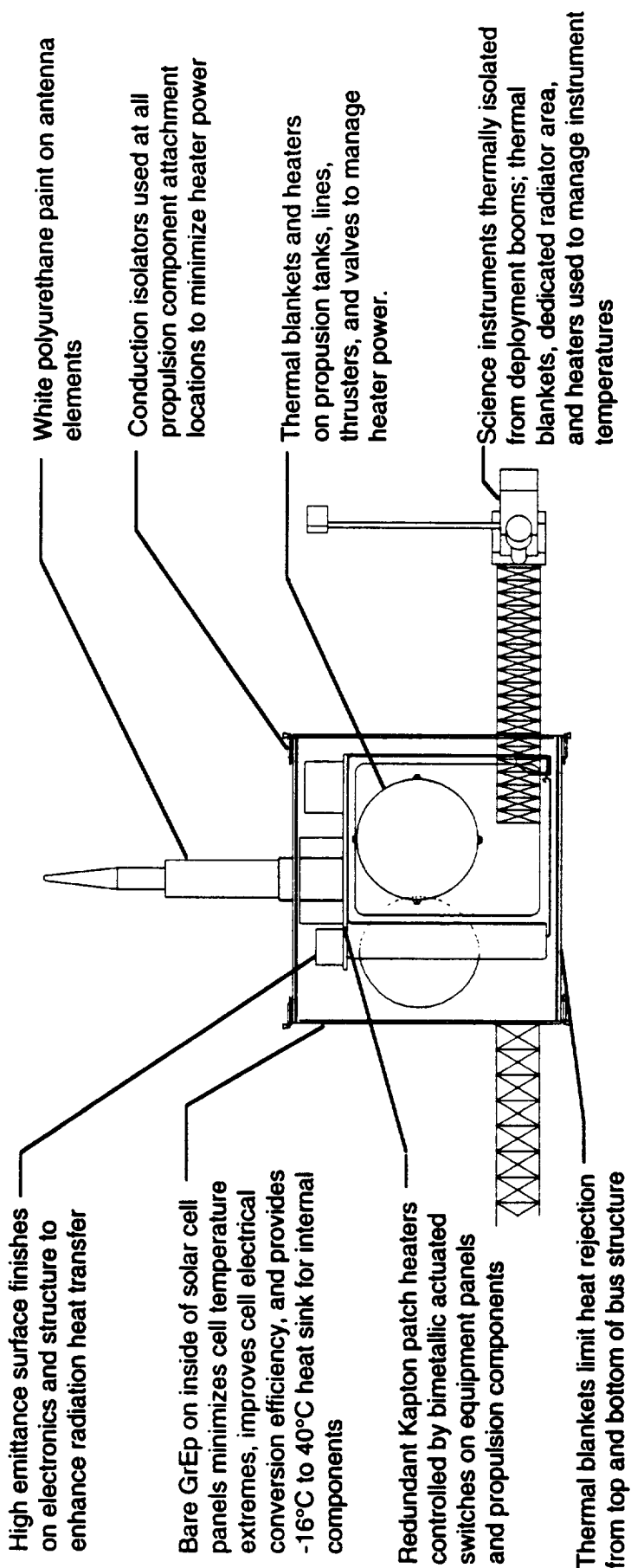
- Lunar Orbit (25 cases)
 - 50 km circular orbit
 - Solar, albedo, and planetshine (hot and cold constants)
 - BOL and 3 year surface finish properties
 - Sun -5° and $+5^{\circ}$ from normal to spin axis
 - Orbit beta angles = 0° , 77° , and 90° (TBR)
 - 48 minute occultation

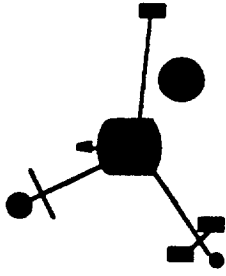


Bus Thermal Design

Thermal Control

LOCKHEED MARTIN





Thermal Design Margins

■ Thermal Control

LOCKHEED MARTIN

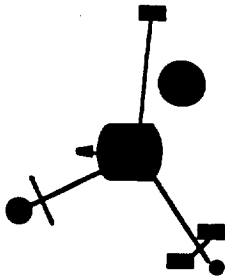


Temperatures Margins

ATP/Operate = Predictions $\pm 10^{\circ}\text{C}$ Minimum @ 1 year
PQ = ATP/Operate $\pm 5^{\circ}\text{C}$ Minimum

Heater Control

- Daily average TCS power less than TBD watts
- Fully redundant bus heater circuits
- 25% heater control authority
- No minimum temperature margin required between predictions and ATP/Op limit if heater controlled

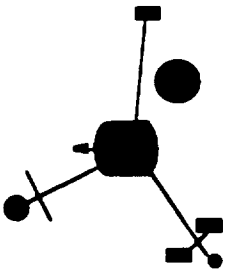


TCS PHSL

Thermal Control

LOCKHEED MARTIN

PROGRAM HARDWARE/SOFTWARE LIST (HARDWARE)		TITLE: Thermal Control Subsystem PROGRAM OFFICE APPROVAL:										STATUS E=EXISTING N=NEW M=MODIFY		CATEGORY D=DEV Q=QUAL R=REL F=FLIGHT S=SPARES					DATE: 29 Aug 95 REVISION: A PAGE: 1 of 1	
ITEM #	WBS #	NOMENCLATURE	DRAWING NO. /	SPEC NO.	STATUS		HOW	MAKE / BUY	QUANTITY PER CONTRACT					SEC	CLASS	REMARKS				
					DESIGN				D	Q	R	F	S				TOT			
	2.1.6.1	Propulsion Heaters (Tanks, Lines)	LMSC P069838			M	N	B				20			20	sim. to (100%); Tayco (Iridium® Drwg)				
	2.1.6.2	Equipment Panel Heaters	LMSC P069838			M	N	B				4			4	sim. to (100%); Tayco (Iridium® Drwg)				
	2.1.6.3	Thermostats	LMSC 1617538			E	N	B				96			96	Texas Instruments				
	2.1.6.4	Thermistors	YSI 44007			E	N	B				15			15	Yellow Springs Instruments				
	2.1.6.5	Silverized FEP Teflon Film		LAC 42-4437-3010		E	N	B				1			1	Shedahl - .1 sq. meters				
	2.1.6.6	Thermal Blankets				M	N	M				1			1	sim. to (100%); 7.5 sq. m (In® Drwg)				
	2.1.6.7	Silverized Optical Solar Reflector	ISBA140-501			E	N	B				1			1	OCLI - 0.4 sq. meters				
	2.1.6.8	Thermal Isolators	LS805-15			E	N	B				80			80	Thrusters, lines, Sls interlocks				
	2.1.6.8	Velcro		LAC 26-4841		E	N	B				1			1	30 meters each - hook and pile				
	2.1.6.9	Aluminum Tape		LAC 24-4451-2200		E	N	B				1			1	Shedahl - 2.0 sq. meters				
	2.1.6.10	Thermostat Clips	2P61438			E	N	B				80			80	P-180 part				



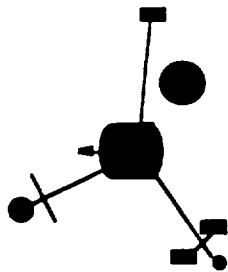
Thermal Control

TCS Hardware

LOCKHEED MARTIN



COMPONENT	SOURCE	DESCRIPTION	HERITAGE
Thermostats	TI	Bi-metallic actuated switch	Existing flight proven design
Bus MLI	LMSC	8 double aluminized mylar inner layers with net spacers and single aluminized Kapton external layers	Existing flight proven design
Prop Line MLI	LMSC	8 layers of embossed double aluminized mylar with net spacers and a single outer layer of aluminized Kapton	Existing flight proven design
Heaters	Tayco	Kapton laminate encasing an electric resistance heater element with 22 AWG lead wires	Existing flight proven design
Thermistors	YSI Fenwall	Temperature transducer	Existing flight proven design
Ag FOSR Tape	Sheldahl	Silverized Fluorinated Ethylene Propylene (FEP) second surface mirror	Existing material with extensive flight history
Al FOSR Tape	Sheldahl	Aluminized Fluorinated Ethylene Propylene (FEP) second surface mirror	Existing material with extensive flight history
Solid State Thermostat	LMSC	Hybrid solid state temperature controller	Completed qualification June 1995
OSR Mirrors	OCU	Silverized Microsheet mirrors	Milstar DFS2



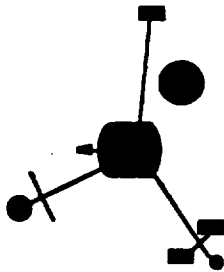
TCS Weight and Power

Thermal Control

LOCKNEED MARTIN

WBS #	Component	Source	Heritage	Quantity	Mass (kg)	Power (W)
2.1.6.1	Propulsion Heaters (Tanks, Lines, Valves)	Tayco	P069838	20	0.73	7.4
2.1.6.2	Equipment Panel Heaters	Tayco	P069838	4	0.14	
2.1.6.3	Thermostats	TI	LMSC 1617538	96	1.1	
2.1.6.4	Thermistors	YSI/Fenwall	YSI 44007	15	0.2	
2.1.6.5	Silverized FEP Teflon Film	Shedahl	LAC 42-4437-3010	0.1 sq. m.	0.04	
2.1.6.6	Thermal Blankets	LMMS	ISBA140-501	7.5 sq. m.	3.65	
2.1.6.7	Silverized Optical Solar Reflector	OCLI	LAC 42-4936-2000	0.4 sq. m	0.3	
2.1.6.8	Thermal Isolators	LMMS	LS605-15	60	0.55	
2.1.6.8	Velcro	Aplix	LAC 26-4841	30 meters	0.13	
2.1.6.9	Aluminum Tape	Sheldahl	LAC 24-4451-2200	2.0 sq. m	0.7	
2.1.6.10	Thermostat Clips	LMMS	2P61438	80	0.2	
	Total				7.74	7.4*

* 7.4 Watts does not include 4 watts for SI thermal control; Total TCS heater power with SI's is 11.4 watts

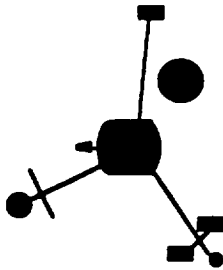


Surface Finish Properties

LOCKHEED MARTIN

Thermal Control

DESCRIPTION	LAC SPEC.	Percent Specularity	NOMINAL ϵ_f	HOT CASE α_s		
				BOL	1 YR	3 YR
SILVERIZED FUSED SILICA OPTICAL SOLAR REFLECTOR (OSR), SPECULAR	42-4430	100	0.80	0.06	0.12	0.17
SILVERIZED FEP TEFLON (FOSR) — 5 MIL SECOND SURFACE MIRROR	42-4437-X010	98	0.80	0.07	0.14	0.22
ALUMINIZED FEP TEFLON (FOSR) — 5 MIL SECOND SURFACE MIRROR	42-4437-X020	93	0.80	0.12	0.20	0.26
ALUMINIZED POLYIMIDE (KAPTON) — 0.5 MIL SECOND SURFACE MIRROR	22-4413-X1X0	92	0.47	0.28	0.37	0.49
ALUMINIZED POLYIMIDE (KAPTON) — 1 MIL SECOND SURFACE MIRROR	22-4413-X2X0	92	0.61	0.42	0.47	0.52
ALUMINIZED POLYIMIDE (KAPTON) — 2 MIL SECOND SURFACE MIRROR	22-4413-X3X0	92	0.73	0.39	0.47	0.56
ALUMINIZED POLYIMIDE (KAPTON) — 3 MIL SECOND SURFACE MIRROR	22-4413-X4X0	92	0.78	0.43	0.52	0.59
ALUMINIZED POLYIMIDE (KAPTON) — 5 MIL SECOND SURFACE MIRROR	22-4413-X5X0	92	0.83	0.50	0.56	0.64
ALUMINIZED TEFLON, POLYIMIDE OR MYLAR FIRST SURFACE MIRROR	22-4413-XXX0 42-4437-X02X 22-4402-XXX0	95	0.04	0.12	0.14	0.15
GLASS FABRIC/ALUMINIZED POLYIMIDE LAMINATE, ALUMINUM SIDE OUT	22-4448	95	0.04	0.12	0.14	0.15
CARBON FILLED POLYIMIDE FILM	22-4703	30	0.88	0.92	0.92	0.92
FLAT WHITE SILICONE — (S13-GLO)	37-4633-0100	2	0.88	0.22	0.35	0.50
GLOSS WHITE POLYURETHANE	37-4462-0200	10	0.87	0.24	0.28	0.55
ALUMINUM FOIL — 1100 ALLOY	24-4451	80	0.04	0.15	0.17	0.19
ALUMINUM SHEET, AS ROLLED SURFACE FINISH 6061-T6 ALLOY	N/A	90	0.04	0.22	0.24	0.26
ALUMINUM SHEET, CLEAR ANODIZED 6061-T6 ALLOY	3463-010100	50	0.82	0.36	0.46	0.55
ALUMINUM SHEET, BLACK ANODIZED 6061-T6 ALLOY	3463-020000	5	0.78	0.78	0.79	0.80
ALUMINUM SHEET, ALODINE COATING 7075-T6 ALLOY	0498	50	0.10	0.35	0.53	0.56

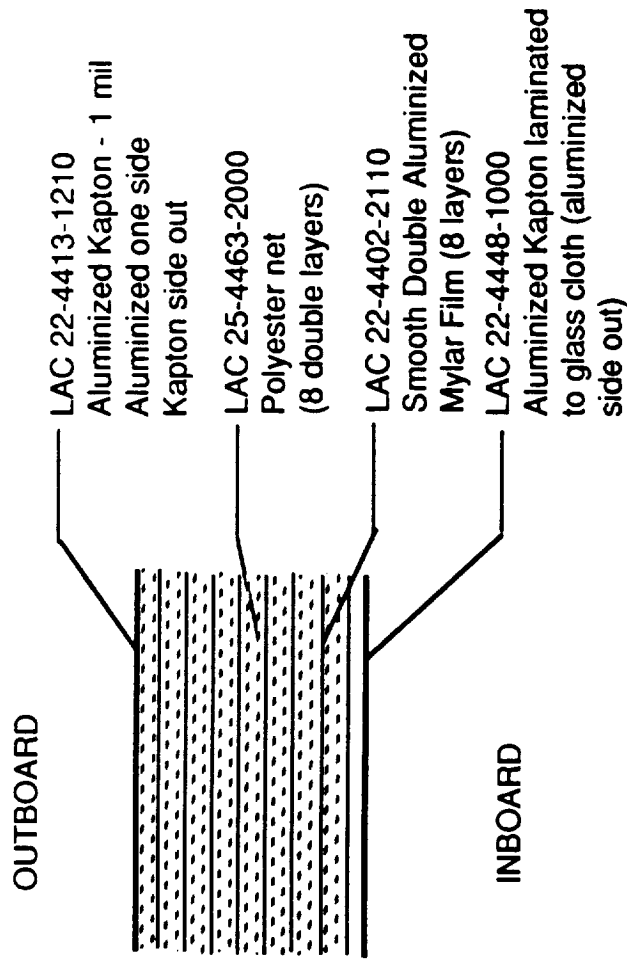


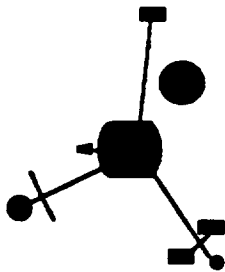
Typical Thermal Blanket Design

Thermal Control

LOCKHEED MARTIN

- Material used on outboard layer of thermal blanket selected to achieve desired solar absorptance to IR emittance ratio
- External blankets with an area of over 1 square foot grounded to structure





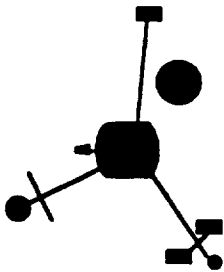
■ Thermal Control

Thermistor Locations

LOCKHEED MARTIN



Location	Quantity	Type
Tank 1	1	YSI 44007
Tank 1	1	YSI 44007
Tank 3	1	YSI 44007
Battery	1	YSI 44007
Transponder	1	YSI 44007
CDH Elec	1	YSI 44007
Battery Control Unit	1	YSI 44007
Gamma Ray Spectrometer	1	YSI 44007
Alpha Particle Spectrometer	1	YSI 44007
Neutron Particle Spec Elec	1	YSI 44007
Solar Panel	1	YSI 44007
Spare	1	YSI 44007
Spare	1	YSI 44007
GRS Heater Controller	2	1617848-002
Total	15	



Thermal Control

YSI Thermistor Error

LOCKHEED MARTIN

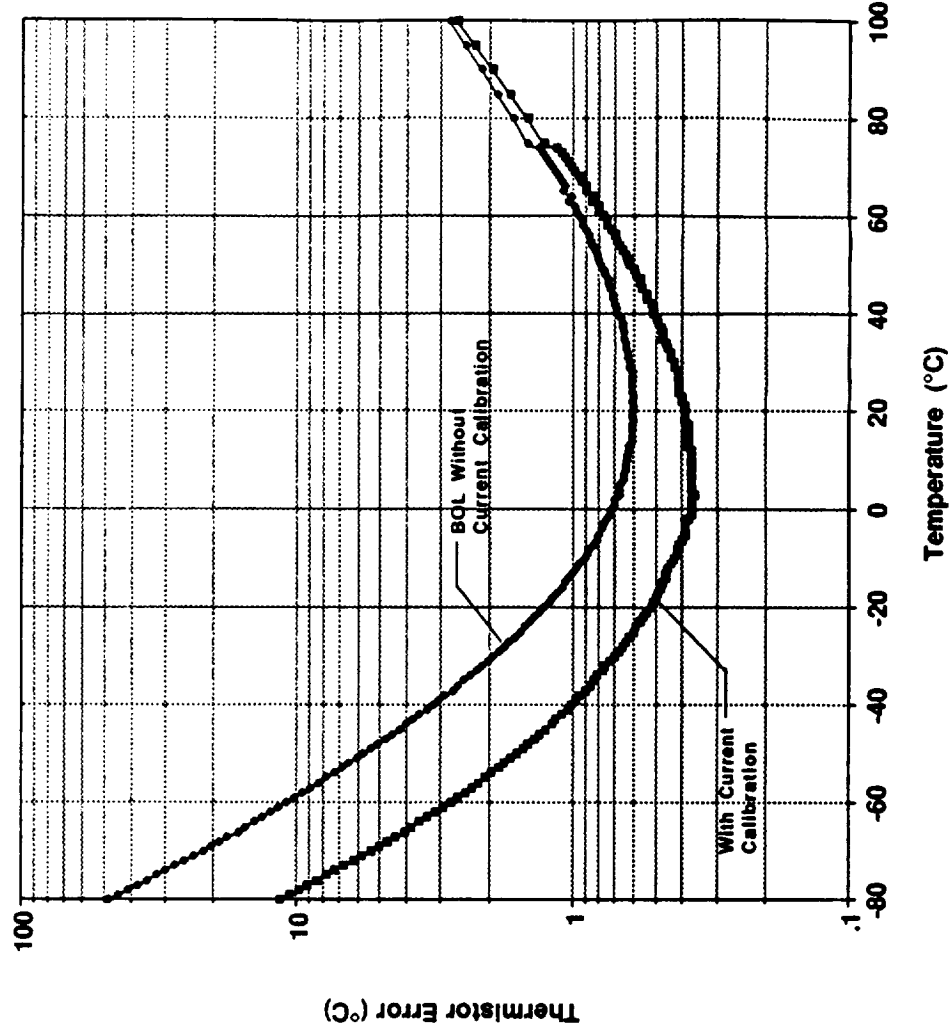
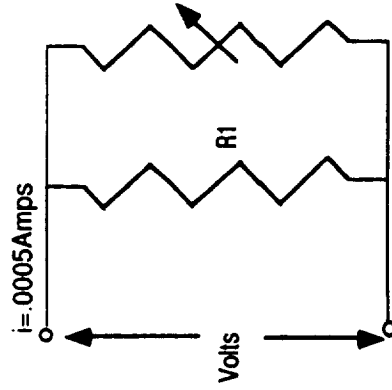


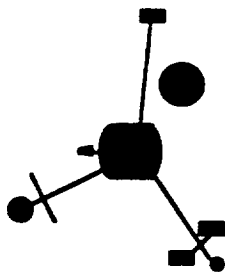
- Errors based Iridium® Bus design with current source
- Voltage source option to be evaluated for LP

R1=10K $\pm 0.7\%$

R2= YSI44007

Volts= 0 to 5.1



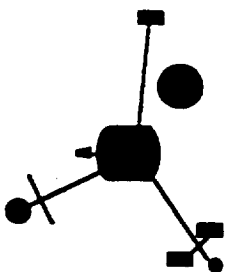


Bus Heater Locations

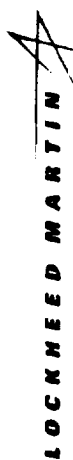
Thermal Control

LOCKNEED MARTIN

Location		Primary Setpoint	Primary Thermostat	Prim Tstat Quantity	Redundant Heater Bus	Redundant Setpoint	Redundant Thermostat	Red Tstat Quantity
Tank 1	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
Tank 2	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
Tank 3	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
Prop Fill Line 1	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
Prop Fill Line 2	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
Prop Fill Line 3	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
Prop Press Line	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
Prop Manifold	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
Prop Manifold	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
Prop Latch Valve	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
RCT 1 Line Internal	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
RCT 1 Line External	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
RCT 2 Line Internal	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
RCT 2 Line External	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
RCT 3 Line Internal	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
RCT 3 Line External	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
RCT 4 Line Internal	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
RCT 4 Line External	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
RCT 5 Line Internal	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
RCT 5 Line External	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
RCT 6 Line Internal	1	55°F to 70°F	1617538-021	2	2	40°F to 55°F	1617538-028	2
Cat Beds	3		Commandable	n/a	4		Commandable	n/a
RCT Valves	1		Vendor Supplied	n/a	2		Vendor Supplied	n/a
Prop Subtotal				4 2				4 2
Equipment Panel A	1	-20°F to -5°F	1617538-015	2	2	-30°C to -15°F	1617538-007	2
Equipment Panel B	1	-20°F to -5°F	1617538-015	2	2	-30°C to -15°F	1617538-007	2
Battery	1	34°F to 39°F	1622122-028	2	2	30°F to 35°F	1622122-022	2
Total				4 8				4 8

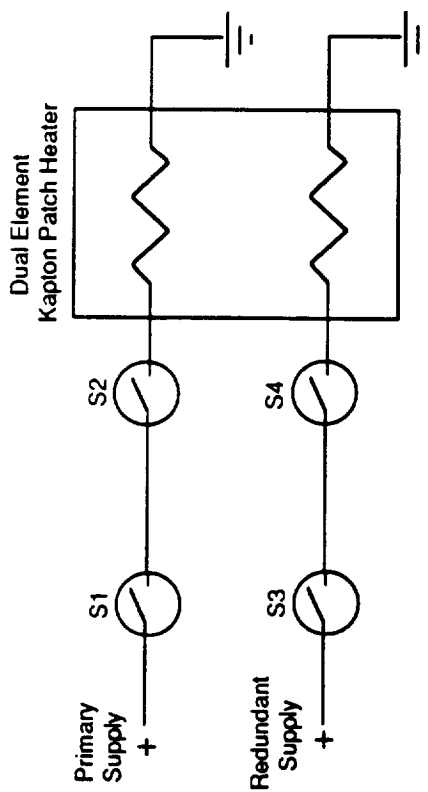


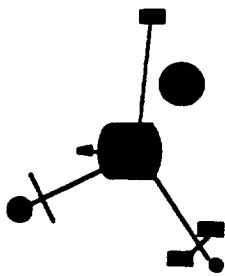
Thermostat Configuration



Thermal Control

- Fully redundant heaters and thermostats
- Primary and redundant heater circuits independently enabled and disabled





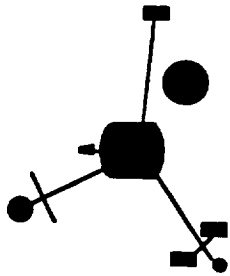
Thermal Control

SI Thermal Design

LOCKHEED MARTIN



Component	Surface Finish Description	Heater Description
Gamma Ray Spec	GrEp housing with Ag OSR on exterior of sides + Ag FOSR top/bottom + aluminized interior surfaces	Heater located on housing with solid state thermostat located in bus
Alpha Particle Spec	MLI blanket with 2 mil aluminized Kapton exterior finish	Bi-metallic actuated heater on housing
Neutron Spectrometer	MLI blanket with 1 mil carbon filled Kapton finish	Bi-metallic actuated heater on electronics
Spectrometer Elec.	Black paint or anodized	Not required
Magnetometer	MLI blanket with 1 mil carbon filled Kapton finish	Mag/ER electronics controlled heater
Electron Reflectometer	MLI blanket with 1 mil carbon filled Kapton finish with TBD cm ² radiator patch	Mag/ER electronics controlled heater
Mag/ER Elec.	MLI blanket with 1 thick carbon filled Kapton finish	Mag/ER electronics controlled heater



SI Heater Power Estimates

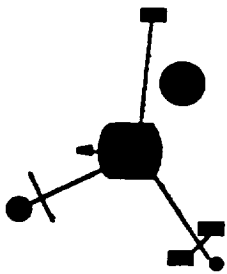
Thermal Control

LOCKHEED MARTIN



Component	Node	Component Dissipation (Watts)	Operate Limits (°C)		BOL Beta=0° Lunar Orbit	
			Min	Max	Htr Watts	Min Temp
APS	2011	0.60	-10	5	0.5	-5.0
Neutron Spec	2024	0.00	-20	20	0.1	-12.0
Neutron Spec Elec	2025	0.10	-20	20	0.0	-12.0
Neutron Spec	2026	0.00	-20	20	0.1	-12.0
GRS housing Top	3019	0.04	-50		1.0	-2.0
GRS housing Bot	3020	0.04	-50		1.0	-2.0
GRS housing Side	3021	0.00	-45	-35	1.0	-32.0
BGO	3022	0.00	-45	-35	0.0	-32.0
Magnetometer	4014	0.06	-20	45	0.0	-16.0
Electron Reflectometer	4015	2.00	-15	45	0.0	70.0*
Mag Elec	4016	2.50	-10	40	0.0	30.0
Total		5.34			3.7	

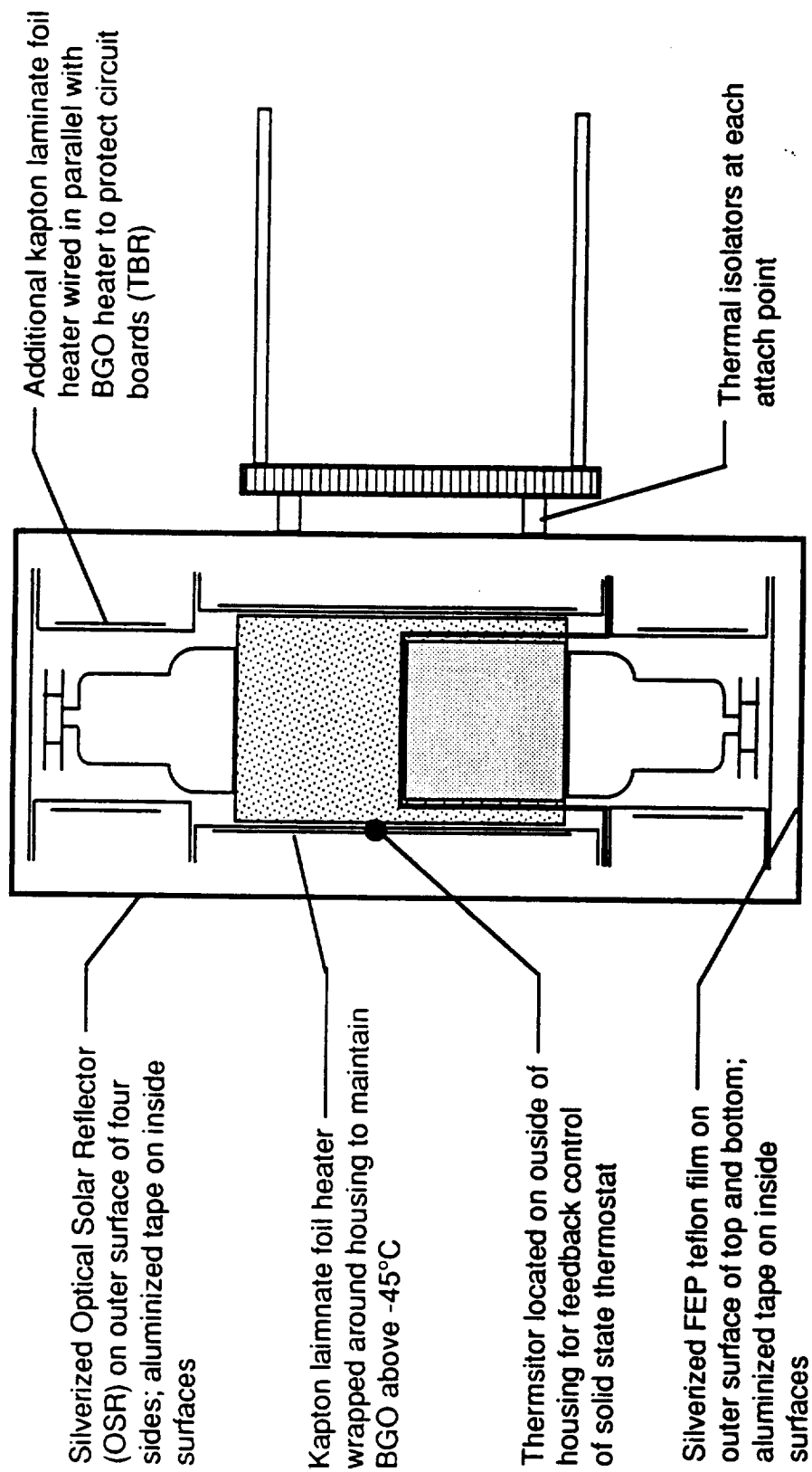
* Radiator patch to be added to limit operating temperature

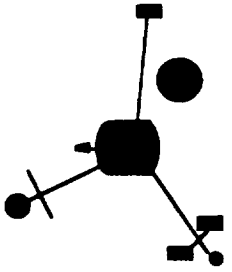


GRS Thermal Design

Thermal Control

LOCKHEED MARTIN





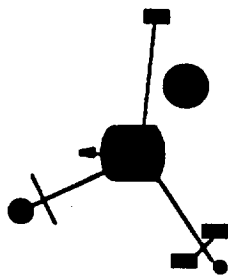
Solid State Thermostat (SST)

Thermal Control

LOCKHEED MARTIN



- SST developed and qualified for LMMS P-180 Program
- Designed and fabricated in house
- SST includes integral voltage regulator that is not required for LP
- Temperature set-point and deadband compatible with GRS requirements
- Design environments and life compatible with LP requirements
- Additional units to be fabricated for LP
- ATP test program tailored for LP (Ambient Functional, TV cycle test, and Burn-in test)



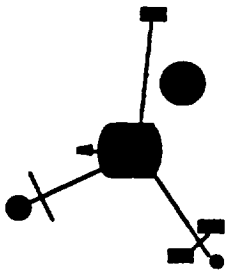
SST Interface Requirements

Thermal Control

LOCKHEED MARTIN



Input Power Interface Requirements		Output Power Interface Requirements	
Power Source	ICU	Voltage Level	20-33 Vdc
Voltage Levels	28 ± 6 Vdc	Max Current	0.77 Amps
Max Current	0.77 Amps	Max Power	25 Watts
Max Power	27.5 Watts	Load	> 42.6Ω
Power Inputs	2 power inputs, diode isolated	Thermostat On Set Point	-40 ± 2.0°F (Pri and Red Module)
Power Return	2 power returns per module	Hysteresis	1.5°F to 3.5°F
Power Return Isolation	>1 MΩ from chassis	Rise Time / Fall Time	< 6 Amp/μsec
Protection	Fused in ICU	Power Return	2 power returns per module
Redundancy	Box level redundant, 2 of 2 thermostats enabled in normal ops.	Power Return Isolation	>1 MΩ form chassis
Duty Cycle	Approx. 36% (50% of orbit rev x 73% Duty cycle)	Duty Cycle	Approx 13% (50% of orbit rev x 27% duty cycle)



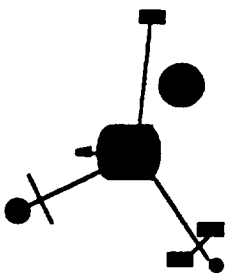
SST Interface Requirements (cont.)

Thermal Control

LOCKHEED MARTIN



Thermistor Interface Requirements	
Signal Type	Differential reference to unreg. return
Thermistor P/N	Fenwall P/N: 1617848-002
Zero Power Resistance	88.5K Ω $\pm$ 2% @ -40°F 94.5K Ω $\pm$ 2% @ -42°F 83.0K Ω $\pm$ 2% @ -38°F 77.9K Ω $\pm$ 2% @ -36°F
Return	One signal return per thermistor
Return Isolation	> 1 M Ω from chassis
Heater Status Bi-Level Analog TLM Interface Requirements (Ground Test Only)	
Signal Type	Single Ended, Positive with respect to unreg. return
Signal Amplitude	Logical 1 = Heater On = +2.0 to +5.0 Vdc Logical 0 = Heater Off = -0.5 to +0.5 Vdc
Source Impedance	10 K Ω maximum resistive, shunted by any value capacitance
Return	One signal return per module
Return Isolation	> 1 M Ω from chassis

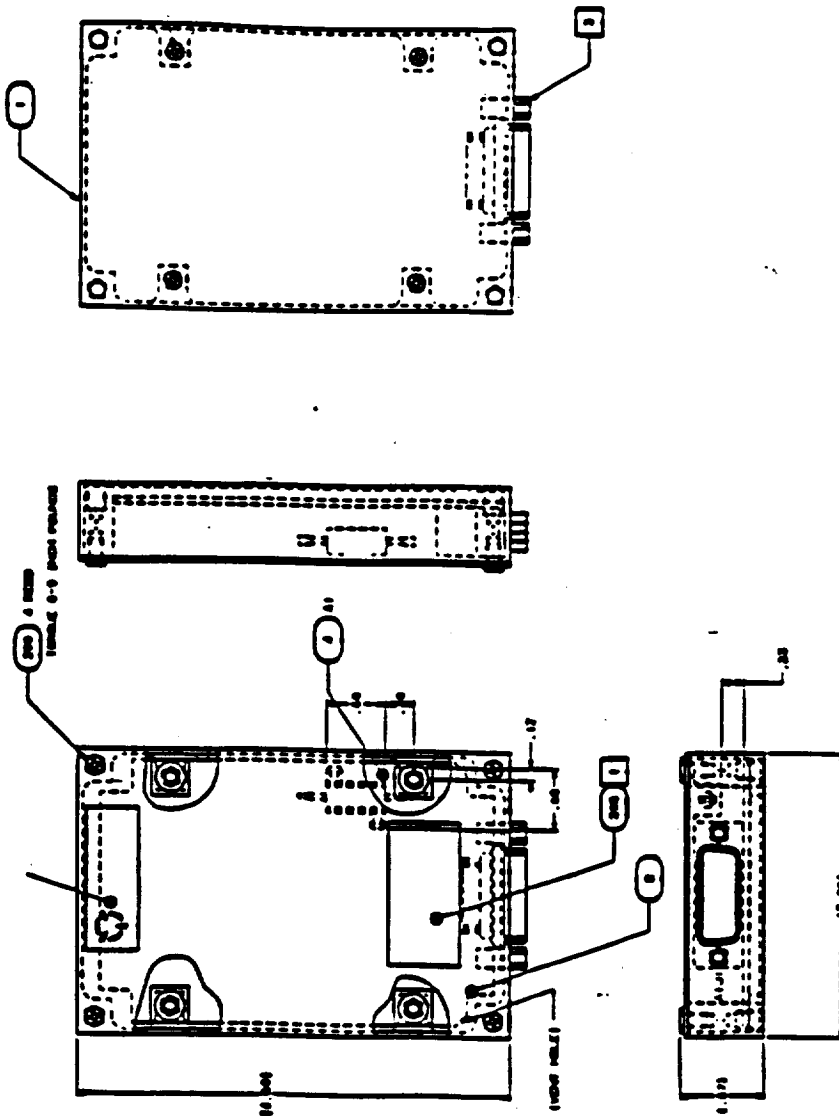
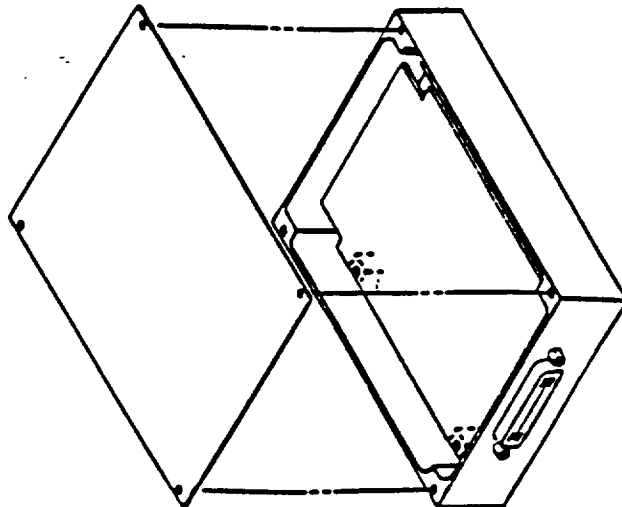


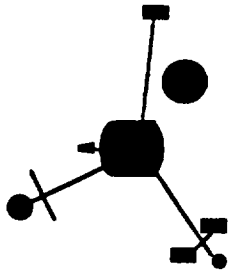
SST Mechanical Design

Thermal Control

LOCKHEED MARTIN

- 1-piece enclosure construction
- 6061-T6 aluminum alloy
- 0.040" thick aluminum 6061-T6 cover
- 0.062" thick 6-layer polyimide board
- Box dimension = 3" x 4.5" x 0.87"
- 4 #8-32 bolts to mount unit to vehicle

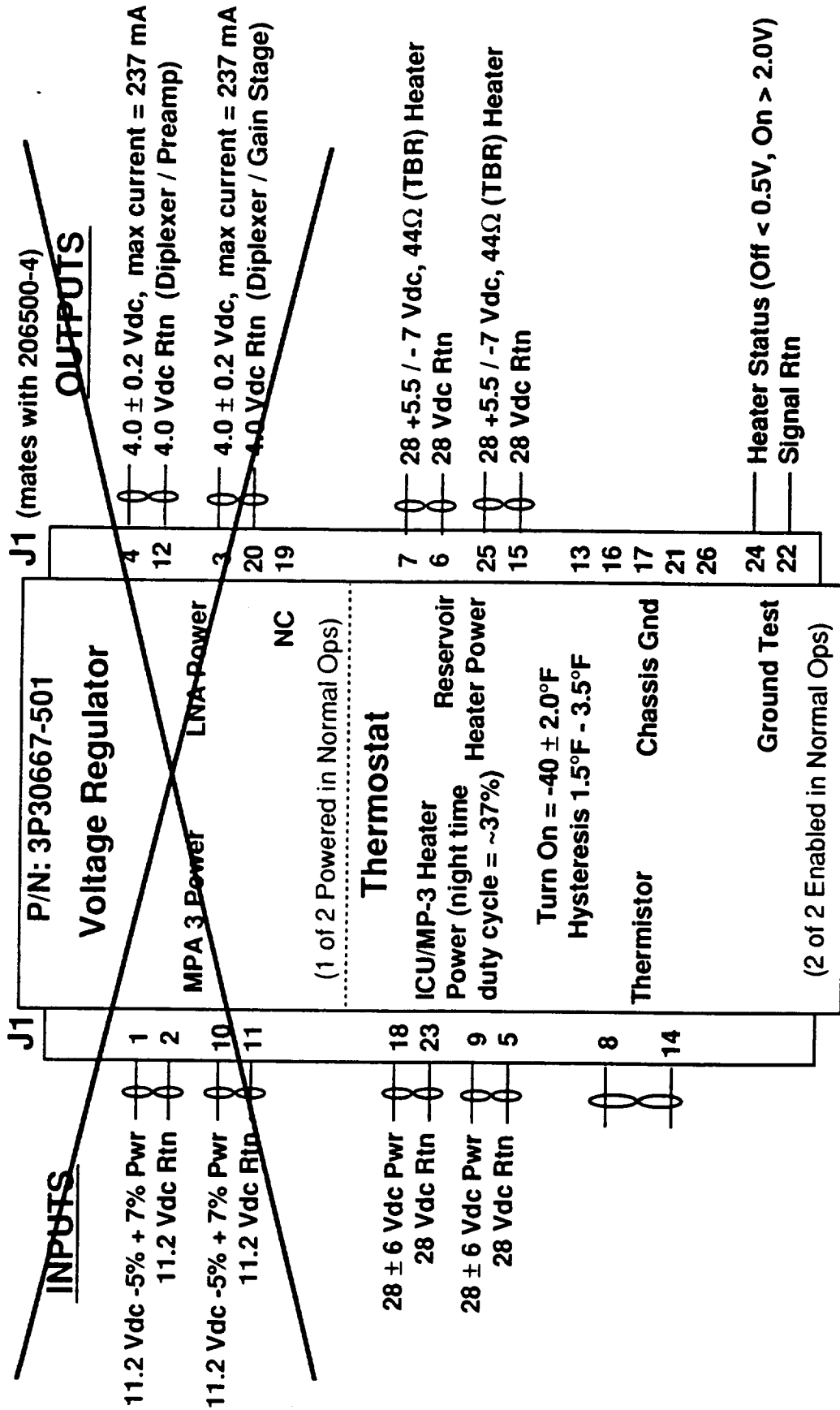


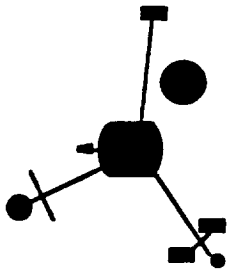


SST Interface Diagram

Thermal Control

LOCKNEED MARTIN

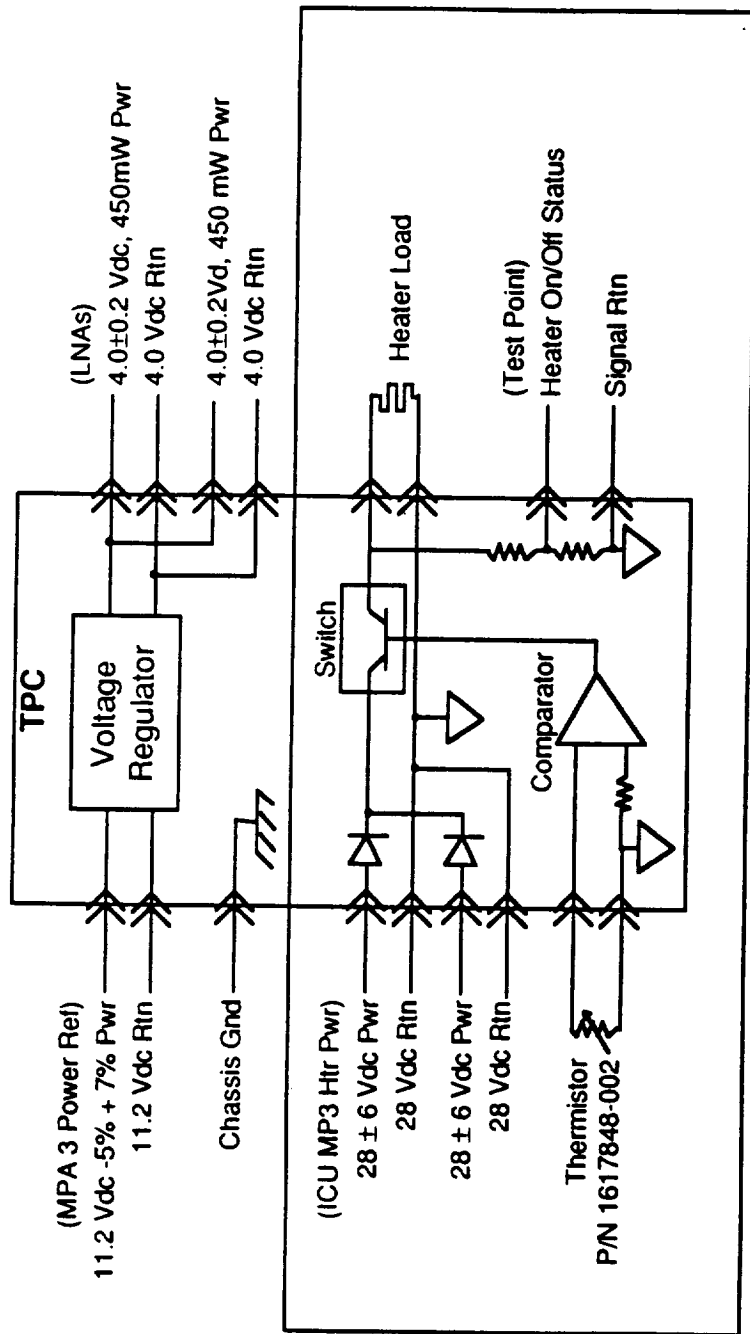




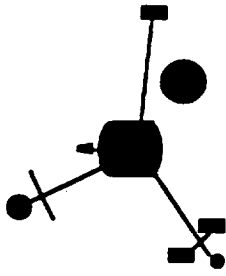
SST Design

Thermal Control

LOCKHEED MARTIN



Required for LP



■ Thermal Control

SST Reliability

LOCKHEED MARTIN



Reliability Requirement:

- The single string component level reliability at 5 years shall be > 0.986 (includes voltage regulator)

Requirement Compliance by Analysis:

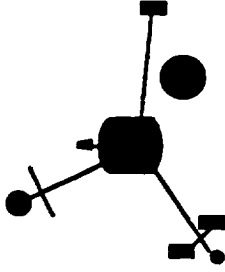
- Electronic parts stress analysis
- Radiation analysis
- Reliability analysis based on part count method and MIL-HDBK-217E, Notice 1
- Component level FMEA
- Physical hardware inspection (to be performed)

Predicted reliability (single string) at 5 years = 0.999 (includes voltage regulator)

- Update of analysis required to reflect latest requirement changes
 - Expected to remain in compliance

Meets 2X predicted radiation environment at 7 years (=88 KRad(Si) total dose).

- One SST component of primary concern
 - LM139A Comparator 20 KRad class-S + 22 mil Tantalum cover and base



Spacecraft Thermal Balance Test

Thermal Control

LOCKHEED MARTIN



OBJECTIVE

- Validate SV thermal math models used for on-orbit temperature predictions
- Verify heater functions, control authority, power consumption, and temperature uniformity
- Verify thermal blanket performance

TEST APPROACH

- Perform steady state thermal balance tests on flight vehicle in conjunction with thermal vacuum acceptance test
- Simulate maximum and minimum environmental extremes and power dissipations using IR lamps, heaters, and vehicle power dissipation
- Maintain equipment within on-orbit temperature limits
- Obtain temperature, heater power, and component power data required to satisfy test objectives

TEST CONFIGURATION

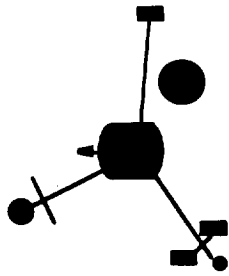
- All flight finishes and thermal blankets installed
- Boom and instruments deployed (TBR)
- Solar array drum (or simulator)
- Approximately 200 test thermocouples and/or calorimeters
- IR lamps and heaters as required



Thermal Control

LOCKHEED MARTIN





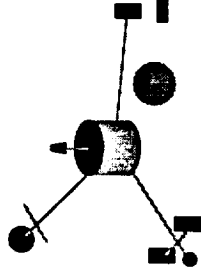
■ Thermal Control

TCS Issues

LOCKHEED MARTIN



- None



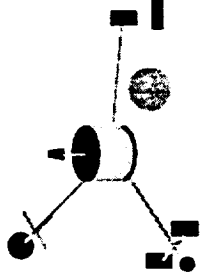
Electrical Power

LOCKHEED MARTIN



ELECTRICAL POWER SUBSYSTEM

Wm. Woodcock

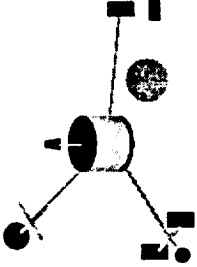


EPS FUNCTIONS

LOCKHEED MARTIN

Electrical Power

- The EPS provides electrical power to the Spacecraft and to its Science Payloads during launch and cruise to the moon and during a one-year science-taking mission in 100-km low lunar polar orbit.
- The EPS accomplishes this function through the use of components which generate, store, and distribute electrical power to the various on-board users.

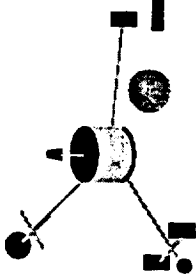


KEY EPS REQUIREMENTS

Electrical Power

LOCKHEED MARTIN

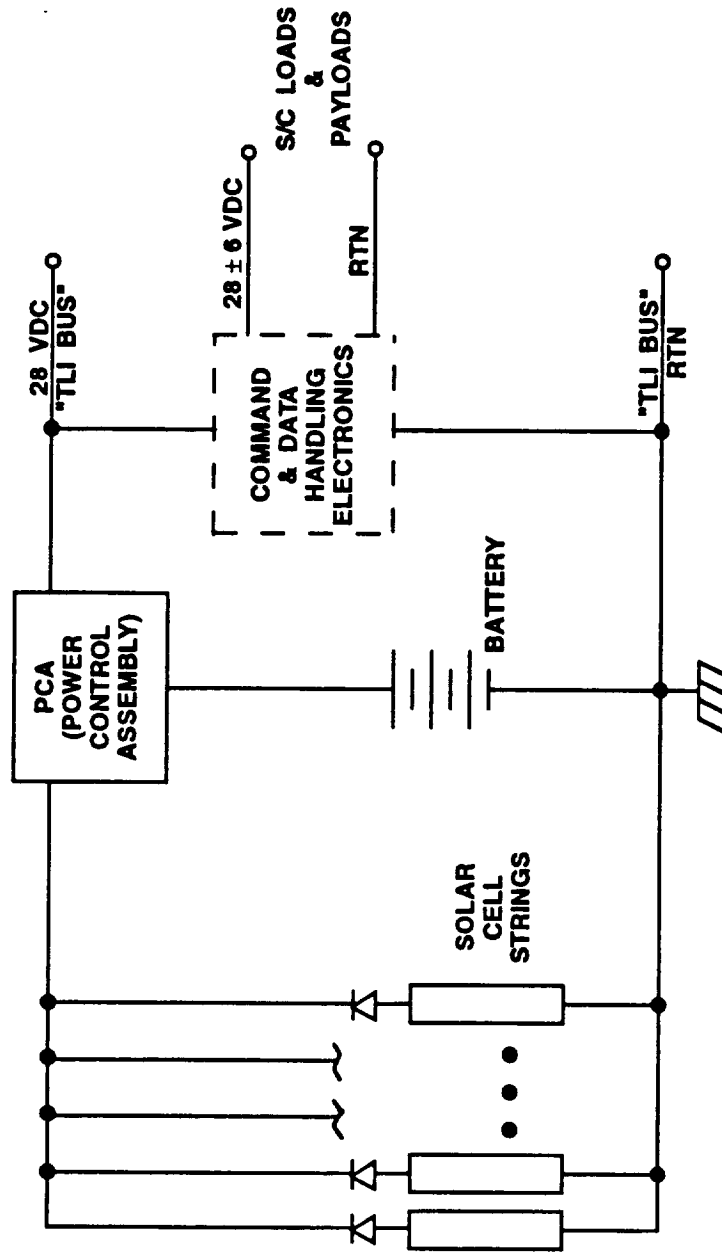
REQUIREMENT	SOURCE
PROVIDE POWER FOR INITIALIZATION, CRUISE, AND ONE YEAR MISSION IN 100 km LUNAR ORBIT	S/C CEI SPEC.
PROVIDE A POWER "BUS" AT 28 vdc $\pm$ 6 vdc (BUS IS PHYSICALLY LOCATED IN C&DH BOX)	EPS CEI SPEC.
118 MINUTE LUNAR ORBIT WITH MAXIMUM 47 MINUTE NIGHT-TIME PASS ($\beta = 0^\circ$ to 90°)	S/C CEI SPEC.
AVERAGE PAYLOAD POWER DEMAND IS A CONSTANT (NO POWER PEAKS)	S/C-to-SI ICD
PROVIDE POWER TO THE TLI STAGE AS WELL AS TO TLI STAGE FUNCTIONS ON THE SPACECRAFT	TLI STAGE CEI SPEC.
PROVIDE ALL WIRE HARNESSES ON SPACECRAFT EXCEPT BETWEEN DPU AND MAG/ER	WBS AND S/C-to-SI ICD



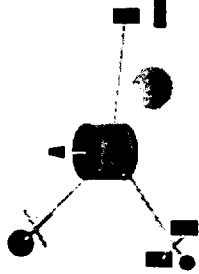
EPS BLOCK DIAGRAM

Electrical Power

LOCKHEED MARTIN



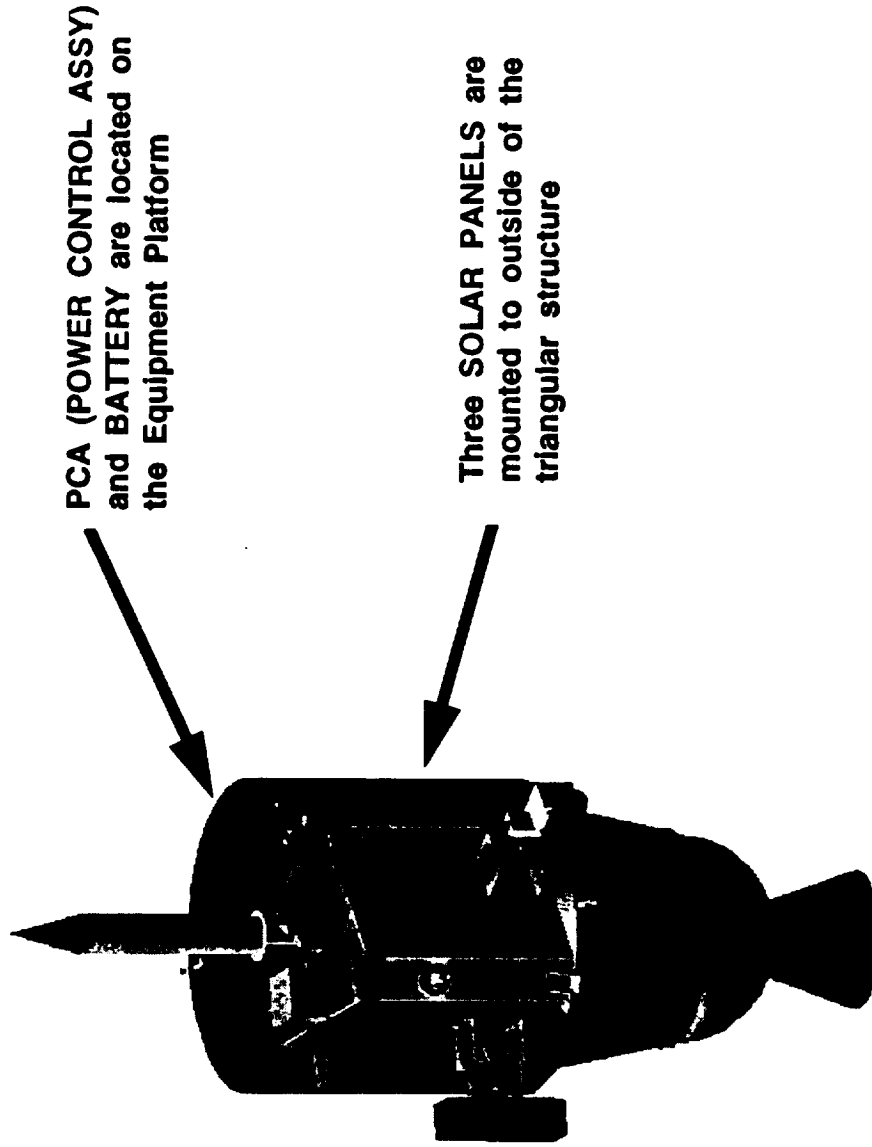
[] = NOT PART OF EPS

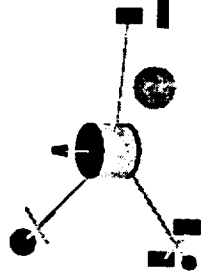


EPS COMPONENT LOCATION ON LP SPACECRAFT

Electrical Power

LOCKHEED MARTIN



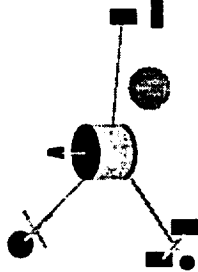


ELECTRICAL POWER BUDGET

LOCKHEED MARTIN

Electrical Power

SUBSYSTEM	AVERAGE POWER DEMAND (Watts)									
	Ascent	S/C Sep. & Chk-Out	SI Calibr.	Cruise (SI's Off)	Lunar Orb. Insertion	Orbit Sunlight	Orbit Nightpass	Lunar Eclipse		
Struct. and Mechanisms	Baseline (W)	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	w. Cont'cy (W)	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	%-Contingency	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Attitude Control	Baseline (W)	0.0	1.0	1.0	1.0	1.0	1.0	1.0		
	w. Cont'cy (W)	0.0	1.1	1.1	1.1	1.1	1.1	1.1		
	%-Contingency	N/A	5%	5%	5%	5%	5%	5%		
Electrical Power (EPS)	Baseline (W)	3.5	11.3	12.4	12.4	12.4	12.4	8.0		
	w. Cont'cy (W)	3.7	12.9	14.3	14.3	14.3	14.3	9.5		
	%-Contingency	5%	14%	16%	16%	16%	16%	19%		
C & DH	Baseline (W)	0.0	10.0	10.0	10.0	10.0	10.0	10.0		
	w. Cont'cy (W)	0.0	13.0	13.0	13.0	13.0	13.0	13.0		
	%-Contingency	N/A	30%	30%	30%	30%	30%	30%		
Communications	Baseline (W)	0.0	37.8	37.8	37.8	37.8	37.8	37.8		
	w. Cont'cy (W)	0.0	39.7	39.7	39.7	39.7	39.7	39.7		
	%-Contingency	N/A	5%	5%	5%	5%	5%	5%		
Thermal Control	Baseline (W)	0.0	15.0	15.0	15.0	15.0	15.0	15.0		
	w. Cont'cy (W)	0.0	19.5	19.5	19.5	19.5	19.5	19.5		
	%-Contingency	N/A	30%	30%	30%	30%	30%	30%		
Propulsion including TLI	Baseline (W)	1.5	0.0	0.0	0.0	0.0	0.0	0.0		
	w. Cont'cy (W)	2.0	0.0	0.0	0.0	0.0	0.0	0.0		
	%-Contingency	30%	N/A	N/A	N/A	N/A	N/A	N/A		
Payloads	Baseline (W)	0.0	0.0	17.0	17.0	17.0	17.0	17.0		
	w. Cont'cy (W)	0.0	0.0	17.0	17.0	17.0	17.0	17.0		
	%-Contingency	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
TOTAL	Baseline (W)	5.0	75.1	93.2	93.2	93.2	88.8	88.8		
	w. Cont'cy (W)	5.7	86.2	104.6	104.6	104.6	99.8	99.8		
	%-Contingency	14%	15%	12%	12%	12%	12%	12%		

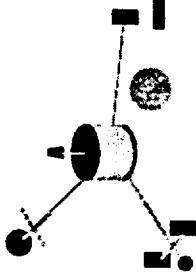


BATTERY RECHARGE POWER

LOCKHEED MARTIN

Electrical Power

SUBSYSTEM	NIGHT-TIME PASS POWER DEMAND in WATTS
Struct. & Mechanisms	0.0
Attitude Control (ACS)	1.1
EPS	9.5
C & DH	13.0
Communications	39.7
Thermal	19.5
Propulsion	0.0
Total S/C Power in Night-Pass	82.8
Total SI Power in Night-Pass	17.0
Total Night-Pass Power Demand	99.8
Energy Expenditure out of Battery During Night-Pass (at 26 v for 47.0 Minutes)	3.0 Amp-Hour
Depth-of-Discharge for One 7 Amp-Hour Battery	43%
Recharge Energy Required (at 105% Recharge Ratio)	3.2 Amp-Hour
Required Recharge Current (over 71.0 Minutes of Sunlight)	2.7 Amps
Recharge Power Required at Solar Array (at 34 v)	91.8 Watts



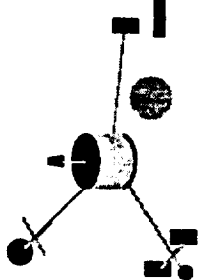
TOTAL EPS POWER REQUIREMENT

LOCKHEED MARTIN

Electrical Power

104.6 WATTS	Required to power the S/C and SI's during the sunlit portion of the orbit
+ 91.8 WATTS	Required to re-charge the battery for the immediately upcoming night-pass
+ 9.8 WATTS	5% Undedicated Power Margin

- Solar Array must be designed to generate 206.2 Watts of power under Worst-Case, End-of-Life conditions



Electrical Power

EPS COMPONENT MASSES

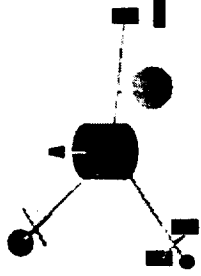
LOCKHEED MARTIN

Estimated Mass

• Silicon S/A (excl. Panel Structure)	7.2 kg (6.1 kg for GaAs)
• 7-Ah Battery (excl. Battery Mount)	8.5 kg
• PCA (Power Control Assembly)	4.0 kg
• <u>Wire Harnesses</u>	<u>6.5 kg</u>
Total :	26.2 kg

* Values are given without maturity-based contingency

** EPS subsystem adjusted allotment is 26.2 kg



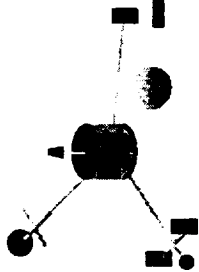
Electrical Power

EPS SUBSYSTEM RELIABILITY ESTIMATE

LOCKHEED MARTIN



EPS COMPONENT	BASELINE EPS DESIGN	
	RELIABILITY DESCRIPTION	ESTIMATED RELIABILITY
SOLAR PANELS	1 of 30 STRINGS CAN FAIL	0.999
BUS REGULATOR	FULLY REDUNDANT	0.998
BATTERY	ONE BATTERY 4000 CYCLES 40% DOD (WORST)	0.990
HARNESSES	REDUNDANT PATHS	0.999
EPS TOTAL		0.986



EPS EQUIPMENT LIST

LOCKHEED MARTIN

Electrical Power

COMPONENT	SUPPLIER	PART NO.	QTY	SIZE	MASS	POWER	PROGRAM HERITAGE
SOLAR PANEL	ASEC or SPL	TBD	3	127 x 119 x 69 cu. cm. EACH	7.2 kg	N/A	VARIOUS
BATTERY	EAGLE- PICHER	TBD	1	15 x 26 x 10 cu. cm.	8.5 kg	N/A	VARIOUS
POWER CONTROL ASSEMBLY	LMMSC	2P23700 + 2P23958	1	10 x 10 x 30 cu. cm.	4.0 kg	7.1 W	LEW
WIRE HARNESSES	AIRCRAFT ENG. INC.	TBD	50 EST.	N/A	6.5 kg	5.3 W	VARIOUS

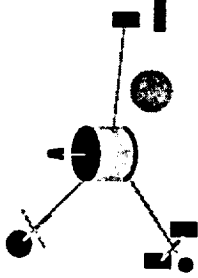
MASS AND POWER VALUES ARE GIVEN WITHOUT MATURITY-BASED BUDGET CONTINGENCY



Electrical Power

LOCKHEED MARTIN

Page 12
ww 9/6/95

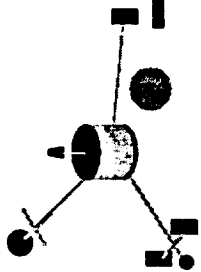


BUS REGULATOR TRADE SUMMARY

LOCKHEED MARTIN 

Electrical Power

- Option #1: Shunt Regulator
 - Requires major down-sizing of P-180 SAR and BCU (1500 W), needs two boxes (Shunt Regulator and Battery Charge Controller), too heavy, also needs a Dissipator Panel
- Option #2: Solid State Switch Network
 - Requires major down-sizing of Iridium® IBE (1200 W), too heavy, runs on 80C86 Processor, serial interface not available for EPS on LP
- ✓ • Option #3: S/A Relay Switcher (a la HST):
 - Use LEW PCA "as is", requires no down-sizing, charge rates similar to LP, lightest and simplest interfaces



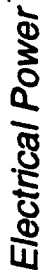
PCA FEATURES

Electrical Power

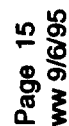
LOCKHEED MARTIN

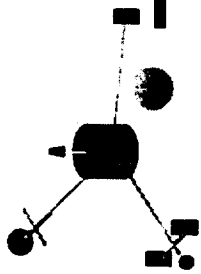


- Flight-proven operation via relay switching of Solar Array and four-level V/T charge control
- Design includes current sensors and redundant LCVO (Low Voltage Cut-Off) circuitry
- All blue-prints and specifications exist. No downsizing required. Thus, build to red-lines for cost effectiveness.
- Designed originally as an assembly on heavy structure and co-mounted with batteries. LP does not require co-mounted batteries and structure. Weighed 44 lbs with batteries and structure. However, for LP will weigh $\approx$ 9 lbs, or 4 kg, without batteries and structure
- LEW charge rate is in required range for LP (i.e. 3.5 Amps)



LOCKHEED MARTIN

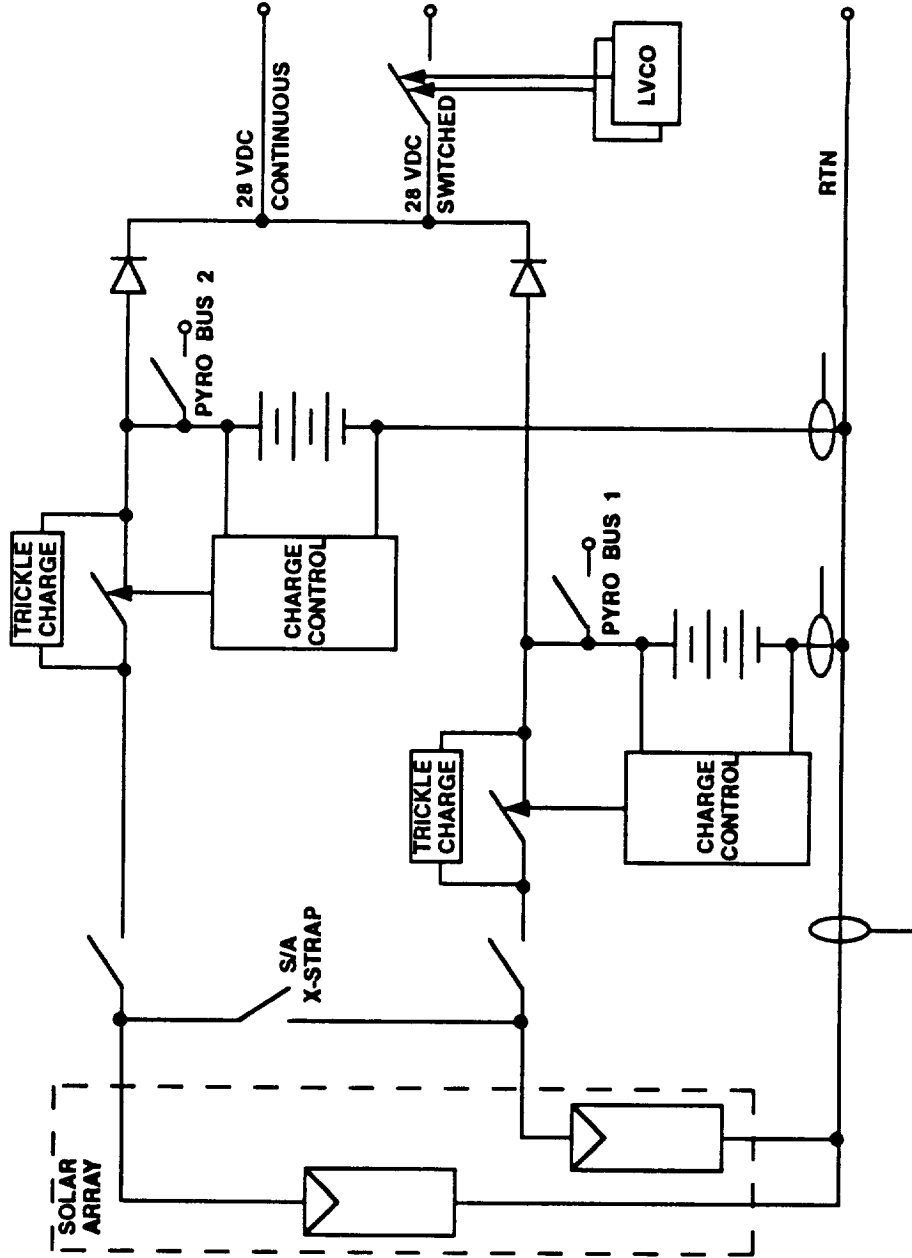




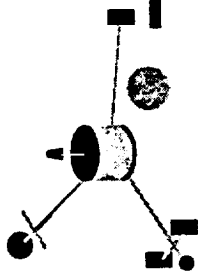
HERITAGE PCA BLOCK DIAGRAM

LOCKHEED MARTIN

Electrical Power



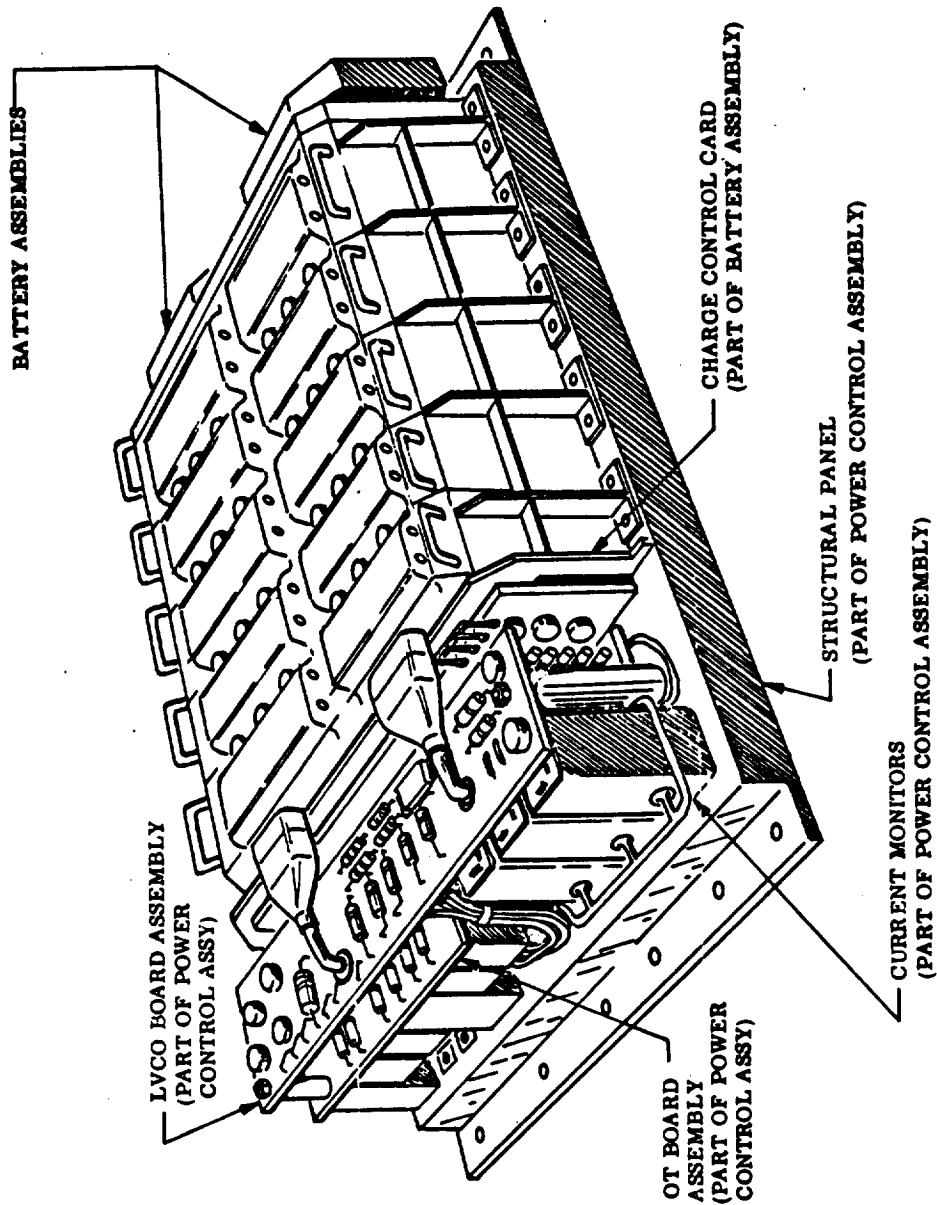
SOLAR ARRAY AND BATTERIES NOT PART OF PCA

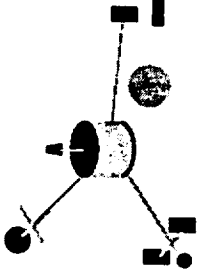


PCA HARDWARE SKETCH

Electrical Power

LOCKHEED MARTIN

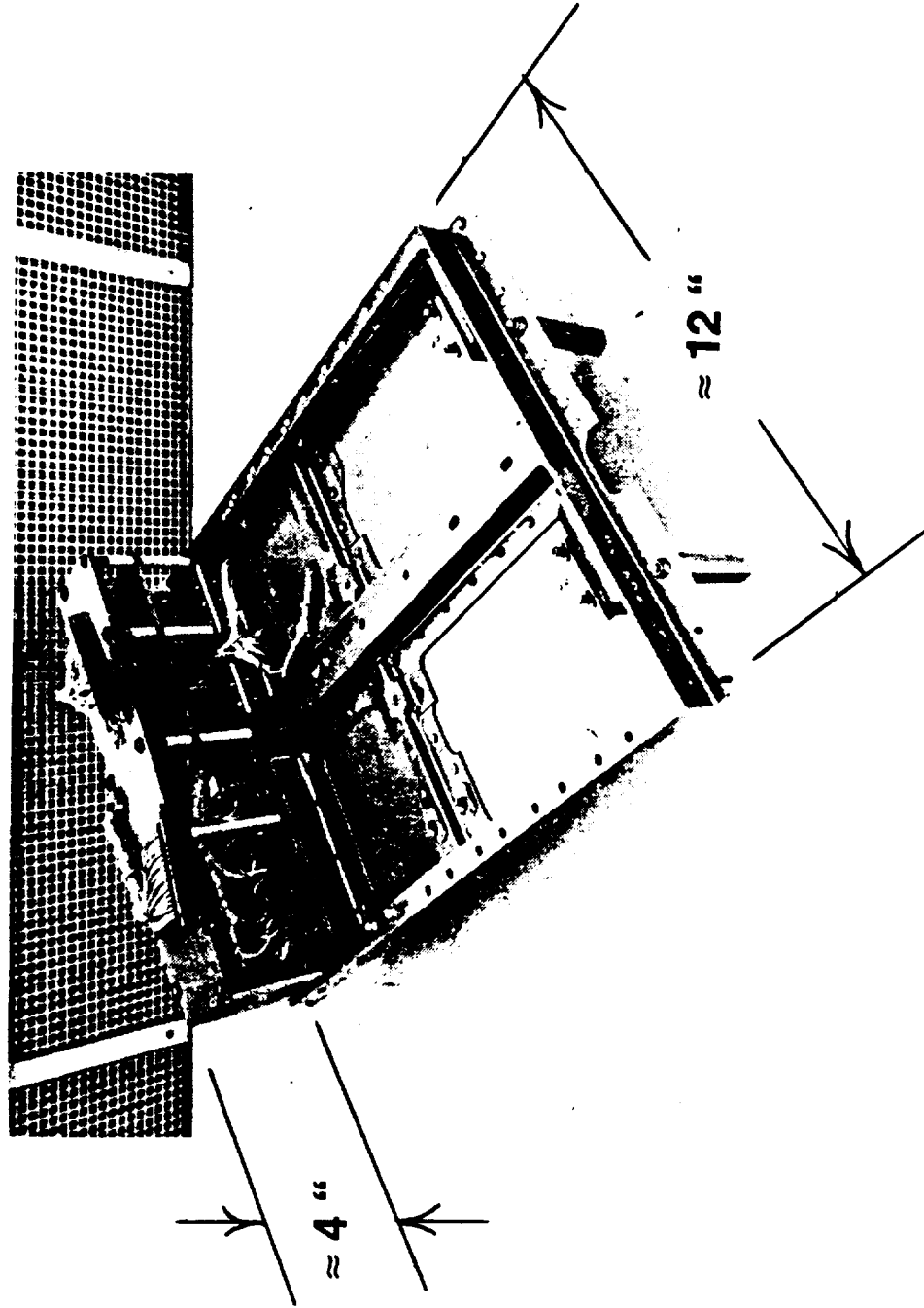


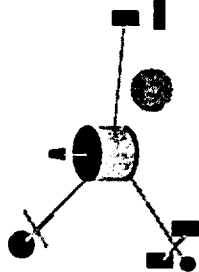


PCA FLIGHT UNIT PHOTO

Electrical Power

LOCKHEED MARTIN

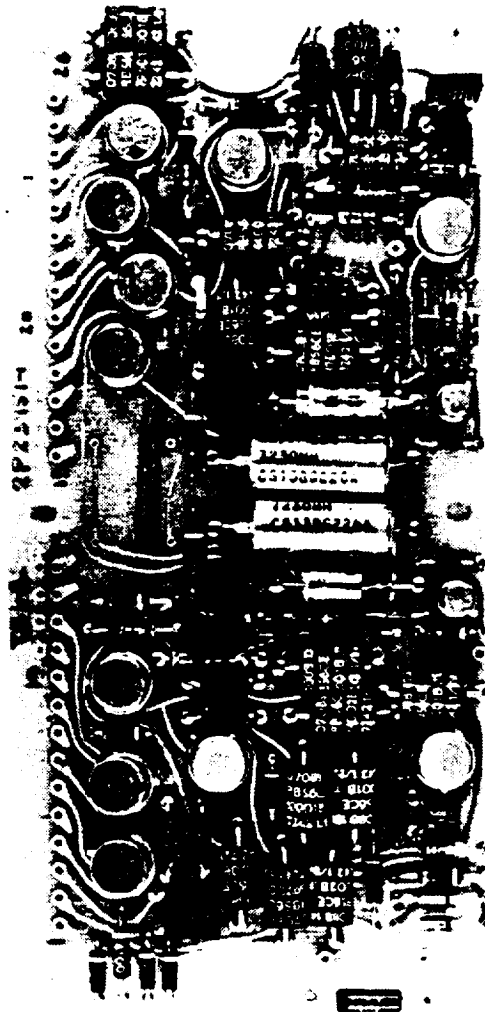




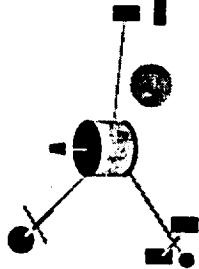
BATTERY CHARGE CONTROLLER

— Electrical Power

LOCKHEED MARTIN 



P/N 2P23958 - CHARGE CONTROL BOARD

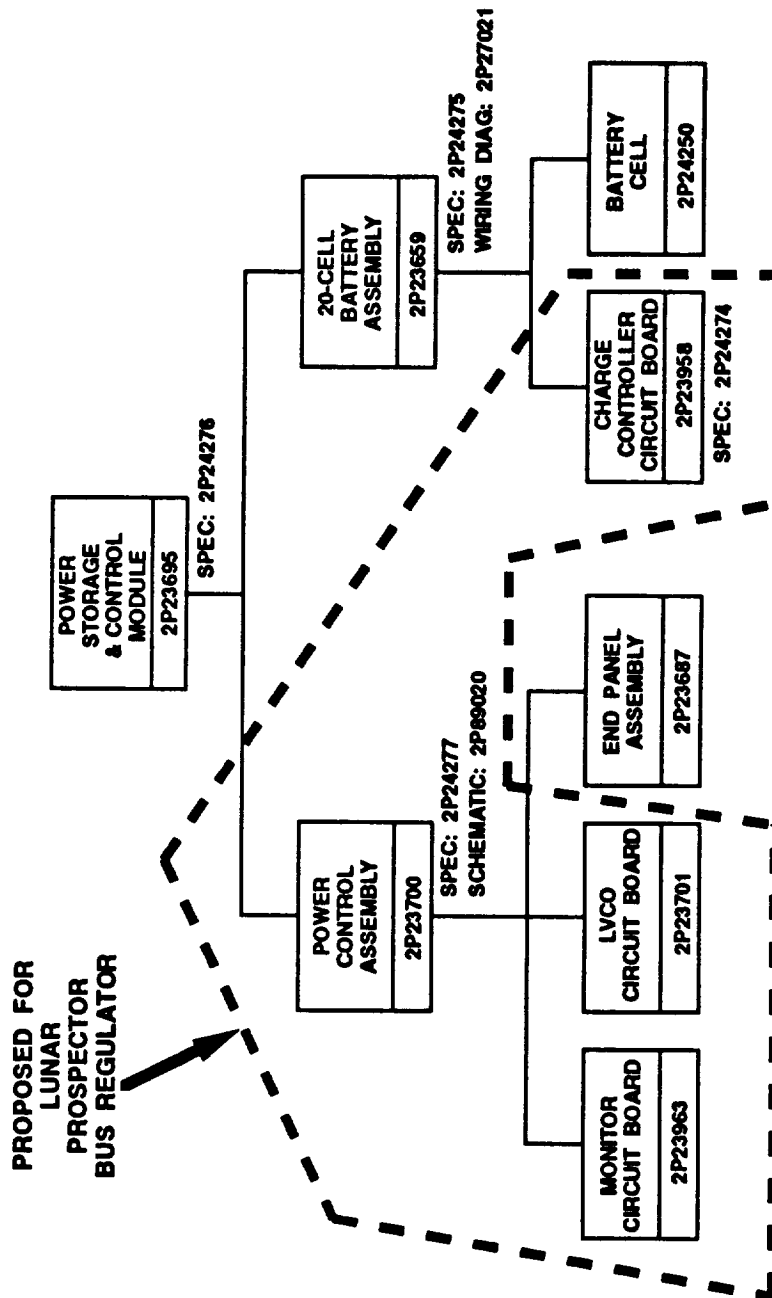


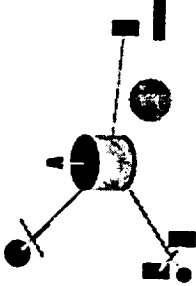
PCA HERITAGE DOCUMENT USAGE

Electrical Power

LOCKHEED MARTIN

LEW PSCM DRAWING TREE



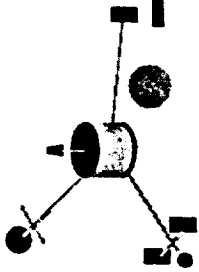


PCA DESIGN IMPLEMENTATION PLAN

Electrical Power

LOCKHEED MARTIN

- Modify to control the charging of two or one (TBR) 22-cell batteries instead of two 20-cell batteries
- Disable "Third Electrode" charge control circuits
- Modify V/T charge control circuits for selected battery
- Reduce quantity of connections for available CMD and TLM functions (See next two charts for LP minimum baseline list)
- Availability of certain electronic parts:
 - Op. Amps. LM108, LM111, LM124 are OK
 - Current Sensor LS41306 is replaceable
 - Hybrid NH0008H or DH0008H needs replacement
 - CMOS Logic, Bi-Polars, Zeners are OK
- Use existing pyro bus Separation Switches for a commandable "TLI-Stage" Bus
- Reduce baseplate and add covers (TBR) to augment the PCA's partial enclosure ?



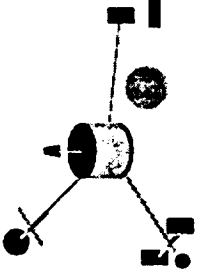
PCA COMMAND LIST

Electrical Power

LOCKHEED MARTIN



FUNCTION	SIGNAL TYPE
1. S/A Terminate	28 VDC Latch
2. S/A Terminate Off	28 VDC Latch
3. Batt #1 Trickle Charge	28 VDC Latch
4. Batt #2 Trickle Charge	28 VDC Latch
5. Batt #1 Full Charge	28 VDC Latch
6. Batt #2 Full Charge	28 VDC Latch
7. Batt #1 Chg Control, Pri	28 VDC Latch
8. Batt #1 Chg Control, Red	28 VDC Latch
9. Batt #2 Chg Control, Pri	28 VDC Latch
10. Batt #2 Chg Control, Red	28 VDC Latch
11. Battery #1 VT Level #1 Select	28 VDC Latch
12. Battery #1 VT Level #2 Select	28 VDC Latch
13. Battery #2 VT Level #1 Select	28 VDC Latch
14. Battery #2 VT Level #2 Select	28 VDC Latch
15. Select LVCO #1	28 VDC Latch
16. Disable LVCO #1	28 VDC Latch
17. Select LVCO #2	28 VDC Latch
18. Disable LVCO #2	28 VDC Latch
19. LVCO Override	28 VDC Latch

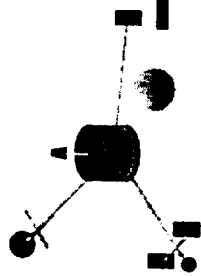


PCA TLM LIST

Electrical Power

LOCKHEED MARTIN 

FUNCTION	SIGNAL TYPE
1. Battery #1 Voltage	Analog
2. Battery #2 Voltage	Analog
3. Battery #1 Current	Analog
4. Battery #2 Current	Analog
5. Solar Array Current	Analog
6. Battery #1 Temp	Passive Analog
7. Battery #2 Temp	Passive Analog
8. S/A Terminate Status	5 Vdc Discrete
9. Batt #1 Full/Trickle Status	5 Vdc Discrete
10. Batt #2 Full/Trickle Status	5 Vdc Discrete
11. Battery #1 VT Level #1	5 Vdc Discrete
12. Battery #1 VT Level #2	5 Vdc Discrete
13. Battery #2 VT Level #1	5 Vdc Discrete
14. Battery #2 VT Level #2	5 Vdc Discrete
15. Batt #1 Pri/Red Cntrl Status	5 Vdc Discrete
16. Batt #2 Pri/Red Cntrl Status	5 Vdc Discrete
17. Batt #1 Overtemp. Status	5 Vdc Discrete
18. Batt #2 Overtemp. Status	5 Vdc Discrete
19. LVCO #1 On/Off Status	5 Vdc Discrete
20. LVCO #2 On/Off Status	5 Vdc Discrete
21. LVCO Bus Off Output	5 Vdc Discrete



BATTERY TRADE STATUS

Electrical Power

LOCKHEED MARTIN

- Shift of the launch date has prompted a re-assessment of battery size (reduce cost and mass)
- EPS now needs a total of only ≈ 7 Ah of battery capacity
- New trade space was confined to NiCd only (i.e. super NiCd):
 - More low capacity flight-proven designs
 - Thermal requirements are less demanding (lower power)
- New baseline is a single NiCd battery, however, analysis is in progress with vendor support to identify cost vs mass benefits of alternate size and quantity



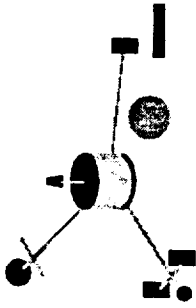
SOLAR ARRAY TRADE STATUS

LOCKHEED MARTIN

- Degradation and loss methodology are established
- Sizing studies are complete:
 - Baseline Design: Silicon
 - Lower Mass Option: GaAs/Ge
- Includes 5% Undedicated Power Margin

Area	Mass*	Cost
5.19 m ²	13.5 kg	RFI
3.75 m ²	10.6 kg	RFI

* Mass includes Panel Structure

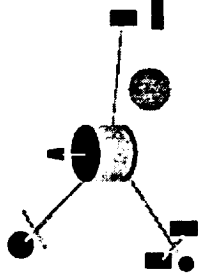


LP BASELINE SILICON CELL

Electrical Power

LOCKHEED MARTIN

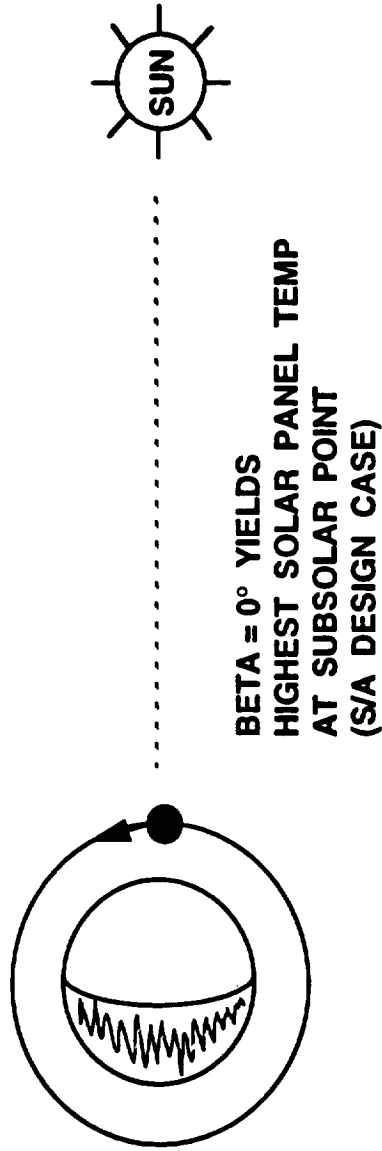
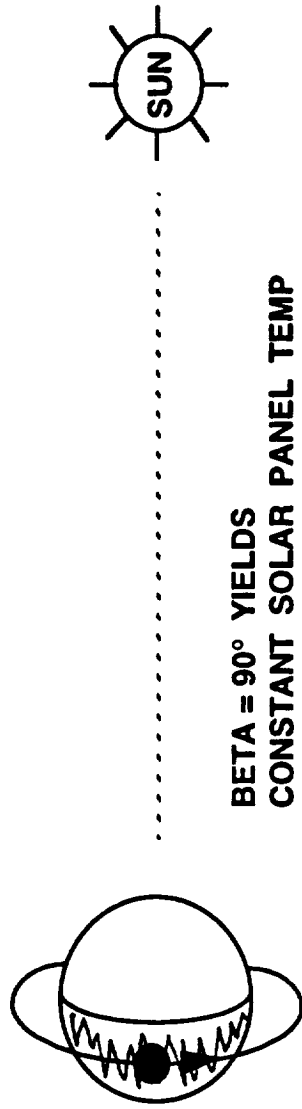
- 4.4 X 4.4 cm SOLDERABLE SILICON 10 Ω -cm BSR CELL
- 12.5% EFFICIENCY @ 28°C & 1 SC (AM0)
- HERITAGE DESIGN:
 - 8 MIL (200 μ m) CELL THICKNESS
 - 28 MIL (700 μ m) COVER THICKNESS
- CHANGE TO THINNER COVERSLIDE (i.e. 4 MIL)
- SPEC & DRAWING EXIST. BOTH AEROSPACE CELL VENDORS HAVE BUILT AND DELIVERED TO THIS SPEC.
- INTERCONNECT DESIGN AND SOLDER PROCESS EXIST
 - CELL + INTERCONNECT ALREADY QUALED TO 3000 DEEP CYCLES (-155°C). LP HAS 4500 CYCLES IN ONE YEAR BUT ONLY A FEW AS LOW AS -130°C. NO RE-QUAL RECOMMENDED

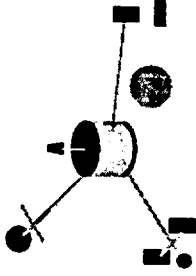


Electrical Power

BETA INFLUENCE ON SOLAR ARRAY

LOCKHEED MARTIN





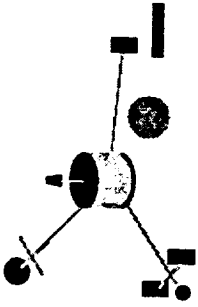
SILICON CELL PERFORMANCE

Electrical Power

LOCKHEED MARTIN

- FOR BETA=0°, PANEL TEMPERATURE = 28°C
- NO REAR-PANEL MLI
- TEMPERATURE APPLIES AT SUB-SOLAR POINT OF ORBIT

	Vpmax	Pmax
BOL, 1 SC (AM0), 28 °C	450 mv	330 mw
RADIATION DEGRADATION LOSS	2 % (EST.)	4 % (EST.)
EOL, 1 SC (AM0), 28 °C, IRRADIATED	441 mv	317 mw
ON-PANEL ΔV - LOSSES (INCL. DIODE)	2 %	2 %
MICRO-METEOROID & UV LOSSES	N/A	2.5 %
CALIB. ERROR & CELL MISMATCH	N/A	1.5 %
5° SUN POINTING ERROR	N/A	0.4%
APHELION	N/A	3.5 %
BOOM SHADOWING LOSSES	N/A	1 %
CELL EOL OUTPUT	432 mv	284 mw

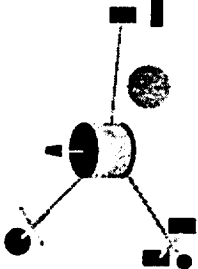


RADIATION ENVIRONMENT ASSUMPTIONS

LOCKHEED MARTIN

- **Approach:** To scope the expected LP losses by comparison to a well-defined program (EOS-PM), rather than by full-blown analysis
- **Mission radiation degradation is due entirely to solar flare protons only**
 - Launch in Oct 1997 (Solar Minimum)
 - One-year mission span
 - 100% rear-side shielding of solar cells
- **Resultant equivalent fluence is estimated at $< 3 \times 10^{13}$ 1 MeV el/cm². This includes a maximum of one "AL" (Anomalously Large) flare event at a confidence level of $> 95\%$**
- **Solar cell percent loss based on P-375 measured degradation curves for selected cell:**

• Voltage degradation:	2% of V _{pmax}
• Power degradation :	4% of P _{max}



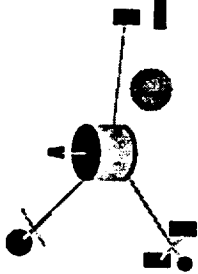
EOS-PM FLARE PROBABILITIES

LOCKHEED MARTIN

Electrical Power

- SOLAR FLARE EVENT PROBABILITY FOR THE UPCOMING EOS-PM MISSION
ACCORDING TO NASA-GSFC "SOLPRO" MODEL

CONFIDENCE LEVEL	NUMBER OF ANOMALOUSLY LARGE FLARE EVENTS		
	EOS MISSION / LAUNCH 2000 (SOLAR MAX AT 2003)		
	1 YEAR	2 YEARS	3 YEARS
80%	1	2	3
90%	1	2	5
95%	1	3	6
99%	2	5	8



SOLAR ARRAY SIZING for SILICON

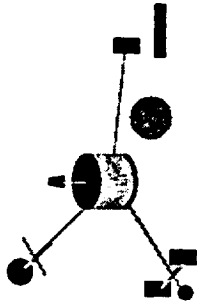
Electrical Power

LOCKHEED MARTIN



SILICON CELLS	$\beta = 0^\circ$
CELL OPERATING TEMPERATURE	28°C
CELL STRING LENGTH FOR 36 V	84 CELLS
QTY OF CELLS REQUIRED FOR 206 W EOL	28 X 84 = 2268
EOL POWER	213 W
QTY OF CELLS IF ONE STRING FAILED	29 X 84 = 2436
REQUIRED SOLAR PANEL AREA	5.19 SQ. M.

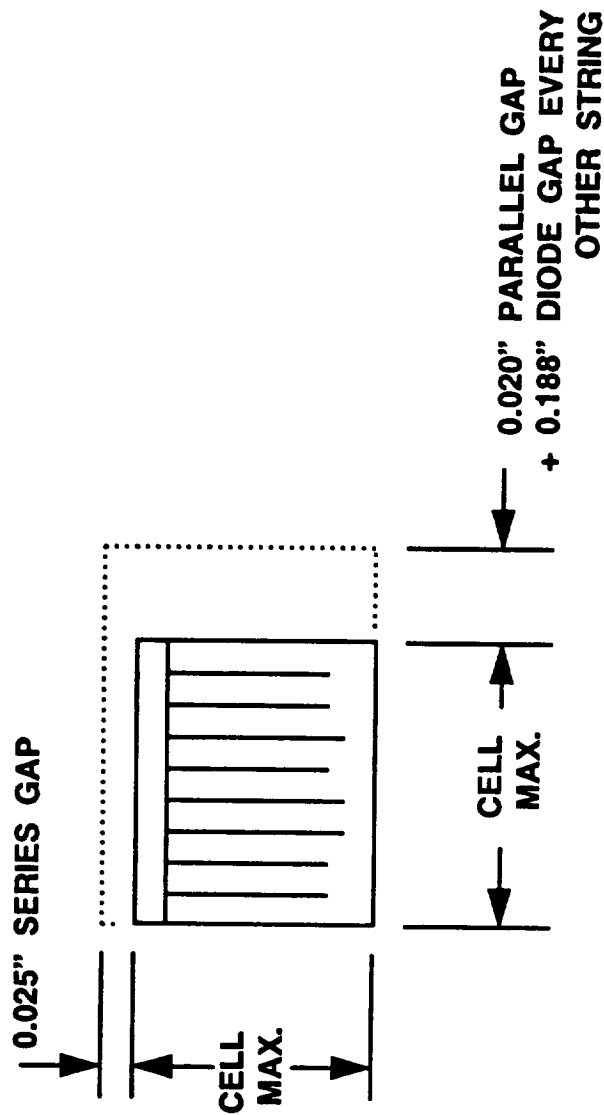
NOTE: THIS ANALYSIS INCLUDES 5% UNDEDICATED POWER MARGIN
AND LOCAL PACKING FACTOR, BUT NOT MAJOR CUT-OUTS



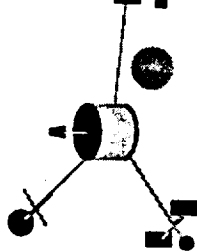
PACKING FACTOR ASSUMPTIONS

LOCKHEED MARTIN

Electrical Power



- SILICON CELL: 1.747"x1.747" → 92.5%
- GaAs/Ge CELL: 2.174"x2.568" → 94.7%

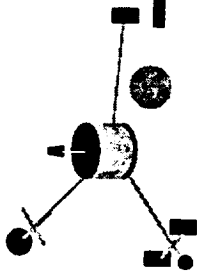


SOLAR PANEL MASS 206 W / SILICON

Electrical Power

LOCKHEED MARTIN

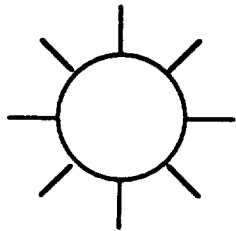
ITEM	QTY PER	LENGTH (Inches)	WIDTH (Inches)	THICKNESS (Inches)	DENSITY (lb/cb.in)	% AREA	WEIGHT (lb)	MASS (kg)	REMARKS
Silicon Solar Cell	1	1.745	1.745	0.008	0.0840	1	0.002046	0.000930	Silicon (2.33 g/cc)
Coverslide	1	1.745	1.745	0.004	0.0793	1	0.000966	0.000439	Fused Silica (2.20 g/cc)
Cover Adhesive	1	1.745	1.745	0.002	0.0389	1	0.000237	0.000108	DC93-500 (1.08 g/cc)
Solar Cell Assy							0.003249	0.001477	
Al Honeycomb Core	1	39.37	39.37	0.38	0.00133	1	0.7737	0.3517	3/8-5056-.001 (2.3 lb/cb.ft.)
Reinforcements, Inerts, Potting	12	1.00	1.00	0.50	0.0577	1	0.3461	0.1573	Epoxy Foam (1.6 g/cc)
Graphite Facesheet	2	39.37	39.37	0.005	0.0577	1	0.8941	0.4064	LAC44-4720 Epoxy (1.6 g/cc each)
Facing Adhesive	2	39.37	39.37	N/A	N/A	1	0.3229	0.1468	FM-73 (0.030 lb/sq.ft.)
Dielectric Layer	2	39.37	39.37	N/A	N/A	1	0.3229	0.1468	FM-73 (0.030 lb/sq.ft.)
Rearside Thermal Treatment	TBD	N/A	N/A	N/A	N/A	N/A	0.0000	0.0000	TBD (Mass in Thermal Mass Budget)
1 Sq. m. Substrate Assy							2.6597	1.2089	
Three Panel Substrate Assys	5.19					1	13.8037	6.2744	
Solar Cell Assy	2436					N/A	7.9156	3.5980	
Cell Interconnect	2509					N/A	1.6886	0.7678	Cells x103% (0.000873 lb per I/C)
Laydown Adhesive	2436	1.745	1.745	0.004	0.0487	0.85	1.2275	0.5579	RTV (1.35 g/cc)
Diode Board Assy	4						0.2000	0.0909	0.05 lb. each
On-Panel Wiring	N/A						3.9370	1.7895	4x100 m of AWG#22(3 lb/1000 ft)
Bypass Diodes (6x29 strings)	174						0.7858	0.3480	(0.5 g each diode, plus 1.5 g wiring)
Connectors	4						0.2000	0.0909	0.05 lb. each
Three Solar Panels							29.7379	13.5172	



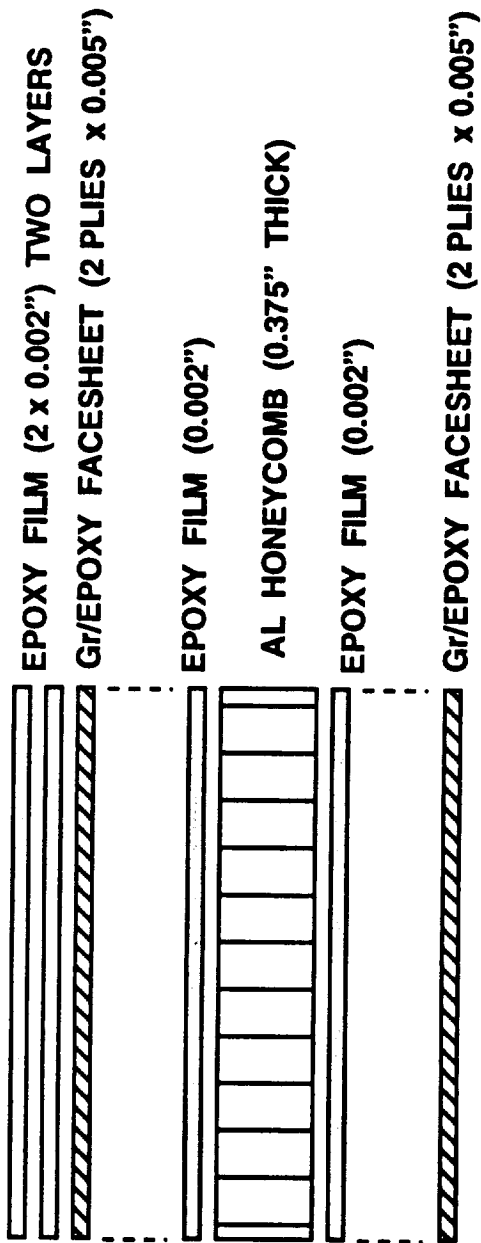
SOLAR PANEL STRUCTURE

Electrical Power

LOCKHEED MARTIN



SOLAR CELL SIDE (OUTSIDE)

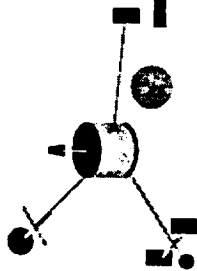


SPACECRAFT SIDE (INSIDE)



LOCKHEED MANTIN

- Page 35
ww 9/6/95



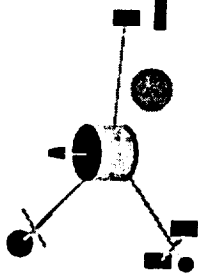
GaAs/Ge CELL PERFORMANCE

LOCKHEED MARTIN

Electrical Power

- FOR BETA=0°, PANEL TEMPERATURE = 49°C
- NO REAR-PANEL MLJ
- TEMPERATURE APPLIES AT SUB-SOLAR POINT OF ORBIT

	Vpmax	Pmax
BOL, 1 SC (AM0), 28 °C	855 mv	870 mw
RADIATION DEGRADATION LOSS	2 % (EST.)	4 % (EST.)
EOL, 1 SC (AM0), 49 °C, IRRADIATED	791 mv	797 mw
ON-PANEL ΔV - LOSSES (INCL. DIODE)	2 %	2 %
MICRO-METEOROID & UV LOSSES	N/A	2.5 %
CALIB. ERROR & CELL MISMATCH	N/A	1.5 %
5° SUN POINTING ERROR	N/A	0.4%
APHELION	N/A	3.5 %
BOOM SHADOWING LOSSES	N/A	1 %
CELL EOL OUTPUT	775 mv	714 mw



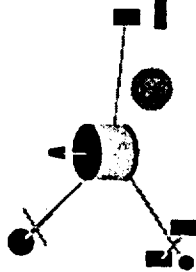
SOLAR ARRAY SIZING for GaAs/Ge

LOCKHEED MARTIN

Electrical Power

GaAs/Ge CELLS	$\beta = 0^\circ$
CELL OPERATING TEMPERATURE	49°C
CELL STRING LENGTH FOR 36 V	47 CELLS
QTY OF CELLS REQUIRED FOR 206 W EOL	20 X 47 = 940
EOL POWER	214W
QTY OF CELLS IF ONE STRING FAILED	21 X 47 = 987
REQUIRED SOLAR PANEL AREA	3.75 SQ. M.

NOTE: THIS ANALYSIS INCLUDES 5% UNDEDICATED POWER MARGIN
AND LOCAL PACKING FACTOR, BUT NOT MAJOR CUT-OUTS

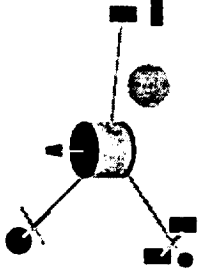


SOLAR PANEL MASS 206 W / GaAs/Ge

Electrical Power

LOCKHEED MARTIN

ITEM	QTY PER	LENGTH (Inches)	WIDTH (Inches)	THICKNESS (Inches)	DENSITY (lb/cb.in)	% AREA	WEIGHT (lb)	MASS (kg)	REMARKS
GaAs/Ge Solar Cell	1	2.568	2.174	0.0055	0.1968	1	0.006044	0.002747	Germanium (5.46 g/cc)
Coverslide	1	2.568	2.174	0.0040	0.0919	1	0.002053	0.000933	Microsheet (2.55 g/cc)
Cover Adhesive	1	2.568	2.174	0.0020	0.0389	1	0.000435	0.000198	DC93-500 (1.08 g/cc)
Solar Cell Assy							0.008532	0.003878	
Al Honeycomb Core	1	39.37	39.37	0.375	0.00133	1	0.7737	0.3517	3/8-5056-.001 (2.3 lb/cb.ft.)
Reinforcements, Inserts, Potting	12	1.00	1.00	0.500	0.0577	1	0.3461	0.1573	Epoxy Foam (1.6 g/cc)
Graphite Facesheet	2	39.37	39.37	0.005	0.0577	1	0.8941	0.4084	LAC44-4720 Epoxy (1.8 g/cc each)
Facing Adhesive	2	39.37	39.37	N/A	N/A	1	0.3229	0.1468	FM-73 (0.030 lb/sq.ft.)
Dielectric Layer	2	39.37	39.37	N/A	N/A	1	0.3229	0.1468	FM-73 (0.030 lb/sq.ft.)
Rearside Thermal Treatment	TBD	N/A	N/A	N/A	N/A	N/A	0.0000	0.0000	TBD (Mass in Thermal Mass Budget)
1 Sq. m. Substrate Assy							2.6597	1.2089	
Three Panel Substrate Assys	3.75					1	9.9737	4.5335	
Solar Cell Assy	987					N/A	8.4209	3.8277	
Cell Interconnect	1017					N/A	0.8942	0.3110	Cells x103% (0.000873 lb per VC)
Laydown Adhesive	987	2.568	2.174	0.004	0.0487	0.85	0.9118	0.4145	RTV (1.35 g/cc)
Diode Board Assy	4						0.2000	0.0909	0.05 lb. each
On-Panel Wiring	N/A						2.3622	1.0737	4x80 m of AWG#22(3 lb/1000 ft)
Bypass Diodes (6x21 strings)	126						0.5544	0.2520	(0.5 g each diode, plus 1.5 g wiring)
Connectors	4						0.2000	0.0909	0.05 lb. each
Three Solar Panels							23.3073	10.5942	

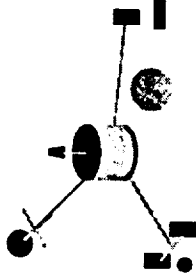


MAST CABLE STATUS

LOCKHEED MARTIN

Electrical Power

- Baseline approach is to tie-wrap all cables to longerons
- Mast Cable List has been iterated several times between the Science Investigators, Spacecraft designers, and the Mast vendor
- Final Mast Cable List (next chart) is feasible for longeron section dimensions which are presently under consideration
- Note that all cables reflect the single-string nature of each Science Instrument



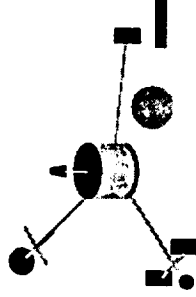
MAST CABLE LIST

Electrical Power

LOCKHEED MARTIN



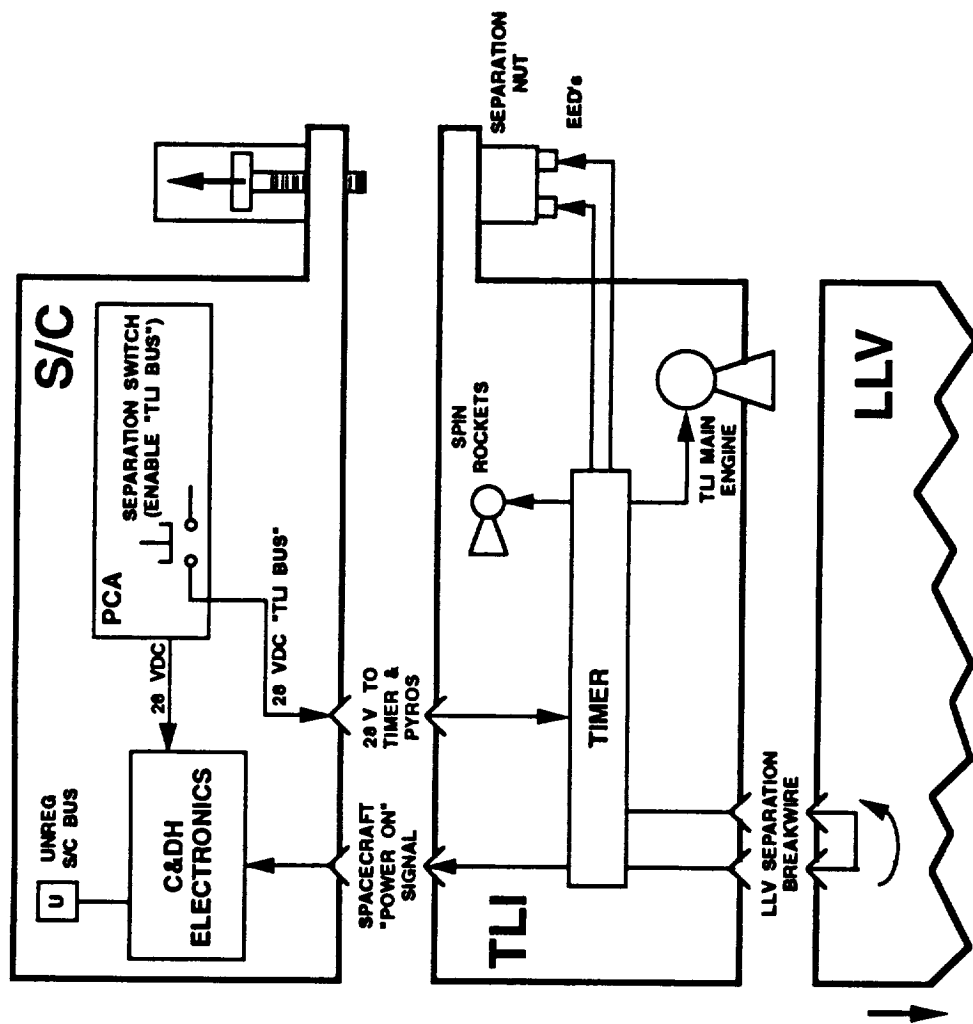
MAST	LONGERON	CABLE TYPES	CABLE FUNCTIONS
Gamma Ray Spectrometer	Longeron #1	• 2 Twisted, Shielded Pairs #22	• +5 and -5 Volt Power & Return
	Longeron #2	• 2 Twisted, Shielded Pairs #24	• BGO Photo-Multiplier Tube Signal and BC454 Photo-Multiplier Tube Signal
	Longeron #3	• 1 High-Voltage Coaxial Cable • 2 Twisted, Shielded Pairs #22	• 2000 V Power to both GRS PMTs • PRI & RED Heater Power & Return
Neutron Spectrometer and Alpha Particle Spectrometer	Longeron #1	• 3 Twisted, Shielded Pairs #22 • 2 Twisted, Shielded Pairs #22	• +25, +5, and -5 Volt Power & Return for APS • +5 and -5 Volt Power & Return for NS
	Longeron #2	• 1 High-Voltage Coaxial Cable • 1 High-Voltage Coaxial Cable	• 2000 V Power to NS He3 Tube w. Cadmium Shield • 2000 V Power to NS He3 Tube w. Tin Shield
		• 2 Twisted, Shielded Pairs #22 • 2 Twisted, Shielded Pairs #22	• PRI & RED Heater Power & Return for NS • PRI & RED Heater Power & Return for APS
	Longeron #3	• 5 Twisted, Shielded Pairs #24 • 2 Twisted, Shielded Pairs #24	• Detector Signals from Each of Five APS Facets • Signals from Each of Two NS He3 Tubes
		• 1 Twisted, Shielded Triad #22	• Primary 28 V Power, Primary Cover Open Power, and Primary Power Return
	Longeron #1	• 1 Twisted, Shielded Pair #26	• Mux'ed Analog Signals & Return
Magnetometer and Electron Reflectometer	Longeron #2	• 2 Twisted, Shielded Pairs #22	• PRI & RED Heater Power & Return
	Longeron #3	• 1 Twisted, Shielded 10-Wire #26	• Digital Signals & Return, including Clock, Strobes, Spin, Gate CMD & TLM, and Data CMD & TLM

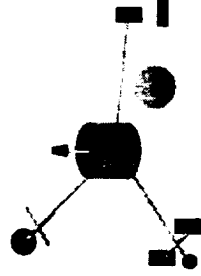


EPS-to-TLI STAGE INTERFACE SCHEMATIC

Electrical Power

LOCKHEED MARTIN



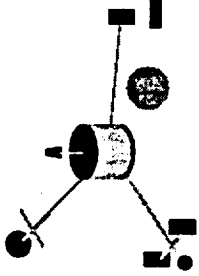


ELECTRICAL INTERFACE - TLJ STAGE WITH SPACECRAFT

Electrical Power

LOCKHEED MARTIN

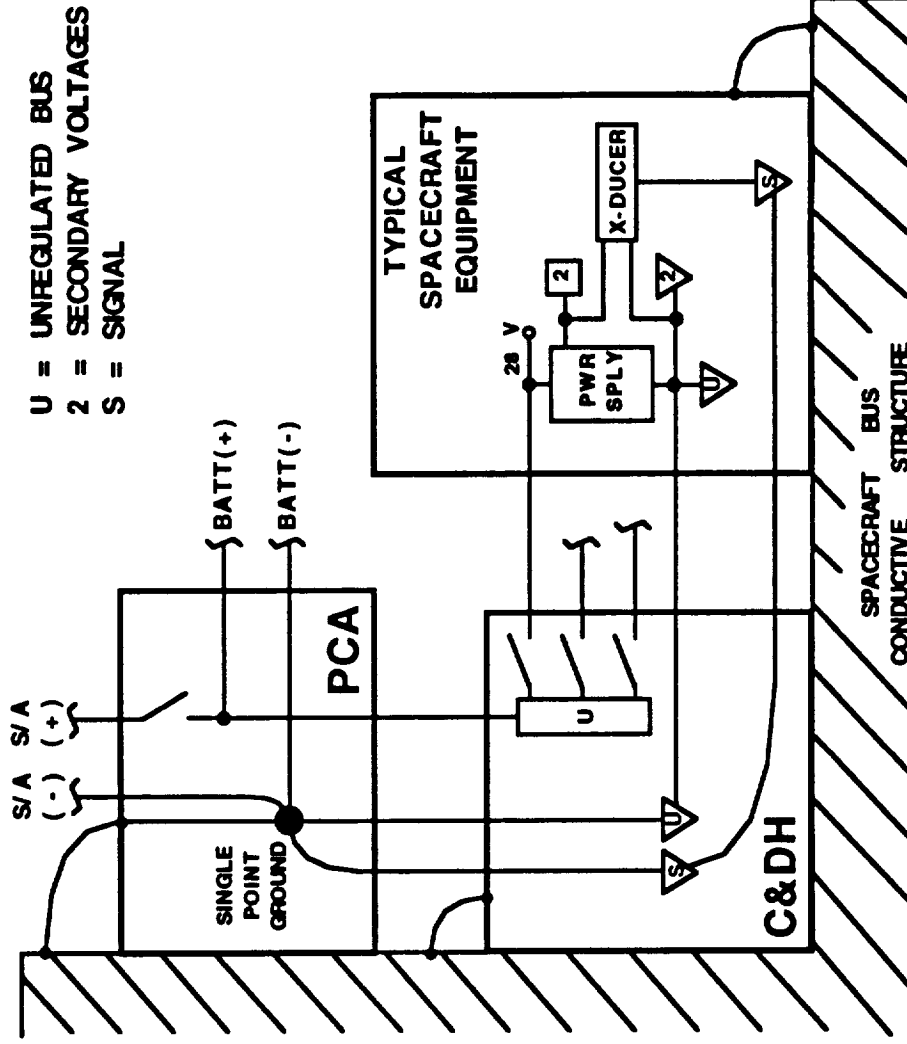
- Power for the TLJ Stage comes from the EPS Battery in the LP Spacecraft (≈ 0.2 Ah required)
- Enable PCA's "TLJ Bus" on Launch Pad via land-line command to close PCS Separation Switches
- Timer on TLJ Stage begins sequencing upon LLV separation
- Timer requires power from EPS for the following functions:
 - arm Spin Rocket via S&A (Safe & Arm) Unit
 - fire Spin Rockets
 - arm TLJ Rocket via S&A Unit
 - fire TLJ Rocket
 - send "POWER ON" Command to C&DH in LP Spacecraft
 - arm Spacecraft Separation Nuts via S&A Unit
 - fire Separation Nuts to separate Spacecraft from TLJ Stage
- Electrical interface configuration:
 - **TLJ-to-EPS:** 28 volt "TLJ Bus":
Two redundant, twisted, double-shielded pairs of AWG #22
 - **TLJ-to-C&DH:** "POWER-ON" Command:
Two redundant, twisted, shielded pairs of AWG #24



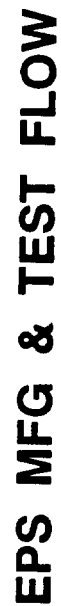
SPACECRAFT GROUNDING SCHEME

LOCKHEED MARTIN

Electrical Power

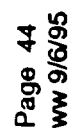


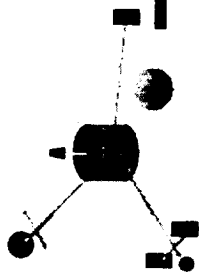
U = UNREGULATED BUS
2 = SECONDARY VOLTAGES
S = SIGNAL



Electrical Power

LOCKHEED MARTIN



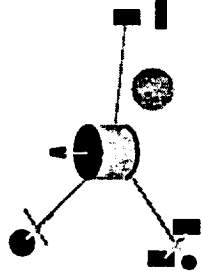


EPS TEST PHILOSOPHY

Electrical Power

LOCKHEED MARTIN

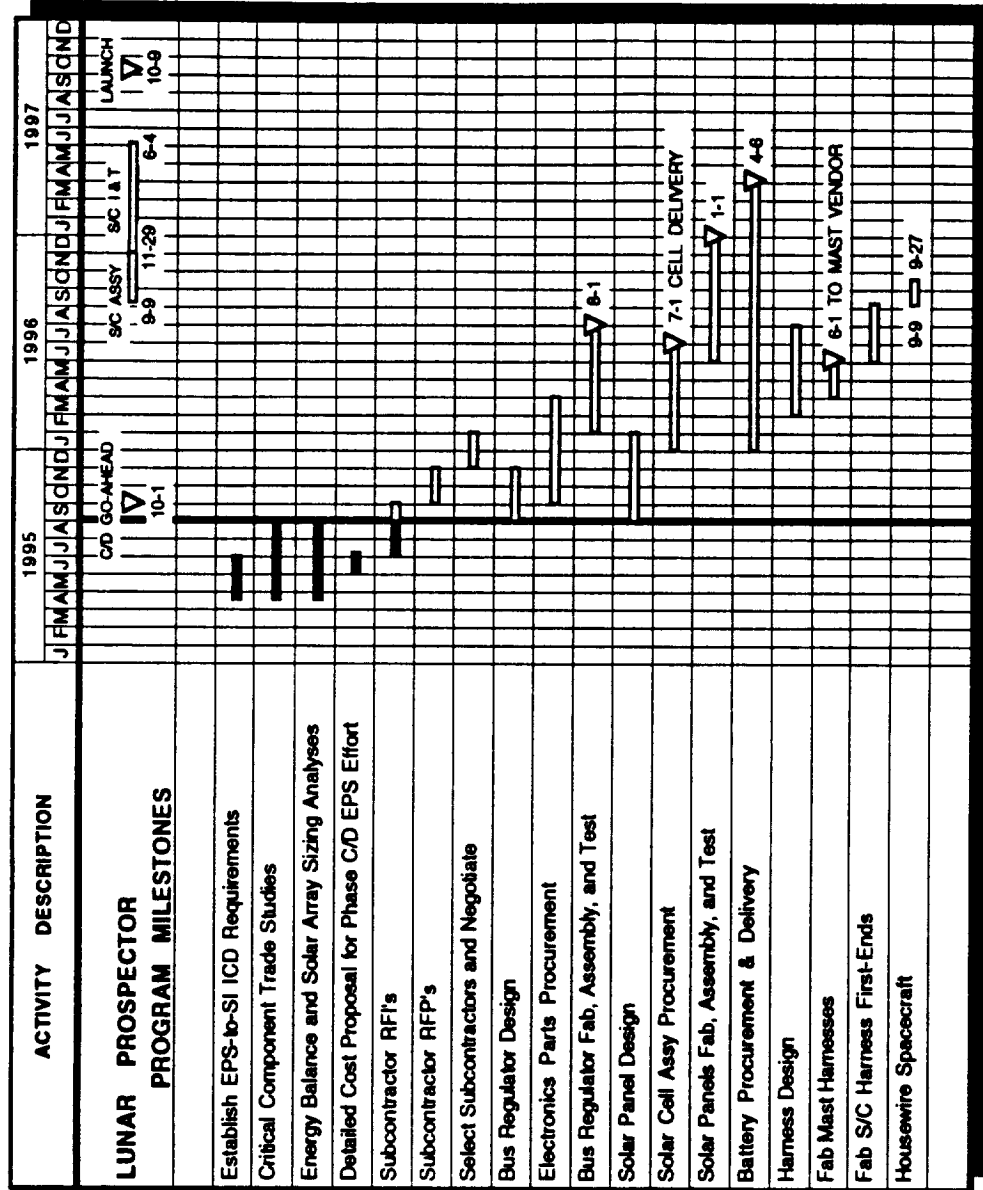
- **Power Control Assembly**
 - No breadboard testing required. The PCA is a flight-proven unit which does not impact the operational stability of other components
 - EMC testing will be performed at higher-level
- **Solar Array**
 - Assume Solar Cell qualification by similarity
 - Perform Coupon Life Test (40-50 cells, 4000 thermal cycles)
 - Proto-qual testing at Solar Panel-level
 - Static Magnetic Cleanliness Test at Spacecraft-level with time-dependant factors by analysis
- **Battery**
 - Battery Cell and Assembly qualification by similarity
 - Limited Cell characterization testing to verify correct V/T-level modifications in PCA
- **Wire Harnesses**
 - ATP all Harnesses
 - Mast Harnesses ATP with Masts at Mast Vendor
- **No EPS subsystem-level testing**

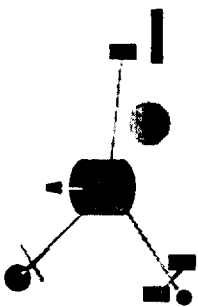


EPS SUBSYSTEM "MASTER" SCHEDULE

LOCKHEED MARTIN

Electrical Power





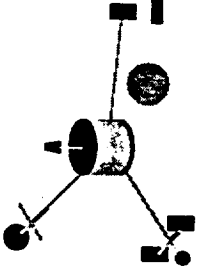
EPS "MASTER" SCHEDULE

Electrical Power

LOCKHEED MARTIN

KEY FEATURES

- Supports assembly and I & T spans of the Program Master Schedule
- PCA heritage blue-prints and specifications will be red-lined for shop use.
- Mast Harnesses already well-defined. Spacecraft Harnesses will be house-wired during assembly of Spacecraft Bus
- RFP's for
 - Solar Panels, Solar Cell Assemblies
 - Battery
 - PCA electronics
- Procurement activity starts after Phase C/D Go-Ahead on Oct. 1
- Procurement lead-time issues?
 - Solar Panels & Cells: No
 - Battery: Schedule is just do-able
 - Electronic parts: No complex work-arounds required
 - Connectors: Always



Electrical Power

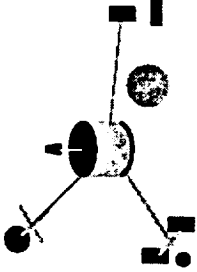
SUBSYSTEM EXTENDED PERFORMANCE

LOCKHEED MARTIN

EPS performance losses from end of year #1 to end of year #3:

- Higher particle fluence?
 - EPS design is for a maximum of one "AL" (anomalously large) solar flare event. This assumption is also valid for three years during a solar minimum period such as the LP mission time frame
- Higher solar cell operating temperatures ? ?
 - Theoretically none, due to particulate radiation model above
 - At worst 1-to-2°C, yielding negligible efficiency decrease
- Increased micro-meteoroid impacts:
 - decrease in photovoltaic current generation is < 1%

Negligible Solar Array power losses for Lunar Prospector extended mission

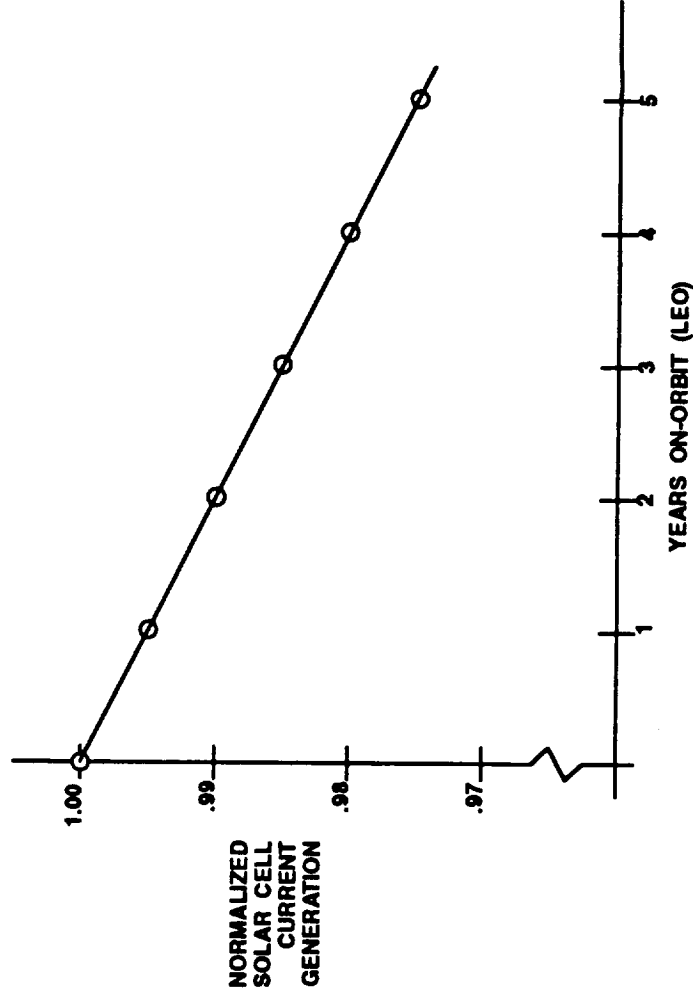


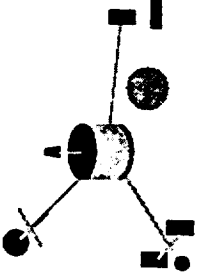
HST MICRO-METEOROID MODEL

Electrical Power

LOCKHEED MARTIN

- Graph shows ESA model used to predict solar cell photovoltaic current losses due to micro-meteoroid impact on cell coverslide for Hubble Space Telescope Program
- Lunar Prospector losses expected to be less due to reduced effect of lunar gravity on micro-meteoroid flux densities





EPS DESIGN ISSUES

Electrical Power

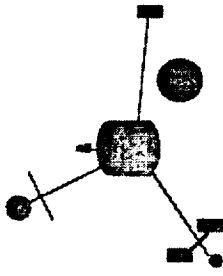
LOCKHEED MARTIN 

- Complete the analysis of cost vs mass benefits of silicon vs GaAs solar cells.

ECD: 9/23/95

- Complete the analysis of cost vs mass benefits of alternate battery size and quantity.

ECD: 9/23/95



- Propulsion

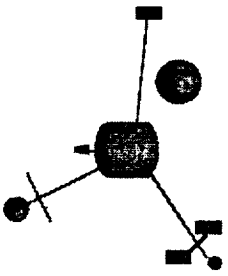
LOCKHEED MARTIN



PROPULSION SUBSYSTEM

R. W. KING

Page 1
RWK



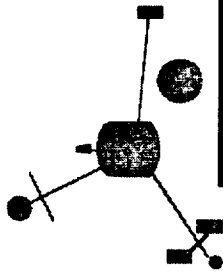
Propulsion Function

■ Propulsion

LOCKHEED MARTIN



- Capture Spacecraft Upon Launch Vehicle Separation
- Provide Spacecraft Spin Rate Control
- Provide Torque for Spacecraft Reorientation
- Provide Impulse for Translunar Mid-Course Corrections (TLC)
- Provide Impulse for Lunar Orbit Insertion (LOI)
- Provide Impulse for Lunar Orbit Maintenance (LOM) Maneuvers
- Provide ΔV Capability Along & Perpendicular to Spin Axis



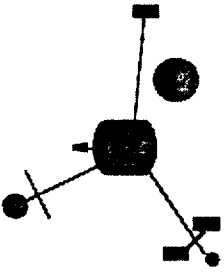
Propulsion

Key Requirements

LOCKHEED MARTIN



REQUIREMENT SUMMARY	ALLOCATION	CURRENT ESTIMATE	COMPLIANCE	VERIFICATION METHOD
TL/Midcourse Corrections ΔV S/C Spec Para #3.4.7	190 m/s	190 m/s	Yes	A,T,S
Lunar Orbit Insertion ΔV S/C Spec Para #3.4.7	860 m/s	860 m/s	Yes	A,T,S
Lunar Orbit Maintenance ΔV S/C Spec Para #3.4.7	120 m/s	120 m/s	Yes	A,T,S
Spin Control & Attitude Control ΔV - S/C Para #3.4.7	20 m/s	20 m/s	Yes	A,T,S
Contingency ΔV S/C Spec Para #3.4.7	240 m/s	355 m/s	Yes	A,T,S
Spacecraft Dry Mass S/C Spec Para #3.5.1	145 kg	145 kg	-	T
System Life S/C Spec Para #1.5.3	1 Yrs	> 1 Yrs	Yes	A,S
Launch Environment S/C Spec Para #3.3.1	Meet Environments Specified in LHSC/Po44654	Meets Environments Specified in LHSC/Po44654	Yes	A,T,S
Pressure Vessel Safety Propulsion Subsystem Spec Para #3.4.2	Factors of safety (proof/burst) • Lines & fittings: 1.5 /4.0 • Propellant tank & Other Components: 1.5/2.0	Factors of safety (proof/burst) • Lines & fittings: 1.5 /4.0 • Propellant tank & Other Components: 1.5/2.0	Yes	A,T,S

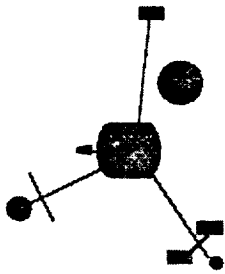


Design Description

- Propulsion

LOCKHEED MARTIN 

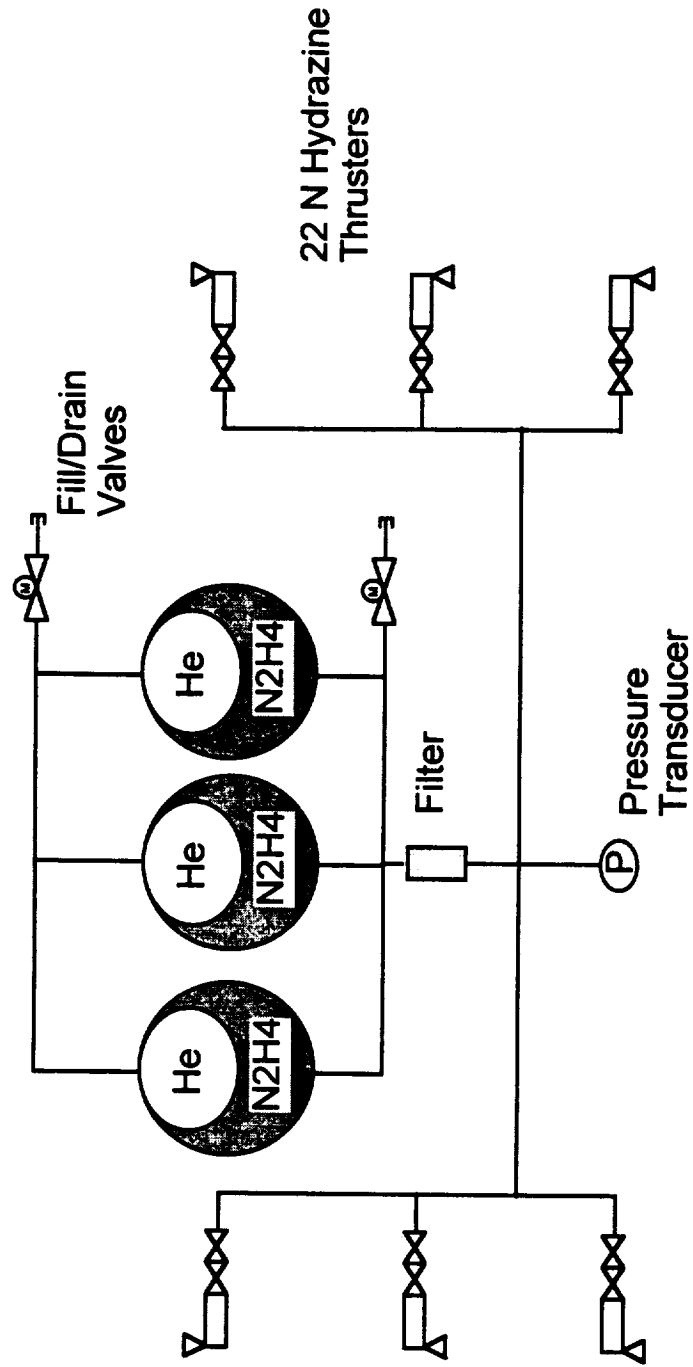
- 3.5 to 1 Single Blowdown Hydrazine System
- Six 22.2 N MR-106E Thrusters
 - (4) Axial Thrusters
 - Provide ΔV Impulse Along Spin Axis
 - Provide Re-orientation Torque
 - (2) Tangential Thrusters Located at S/C C.M.
 - Provide ΔV Impulse Perpendicular to Spin Axis
 - Provide Spin Rate Control Torque
- Three Spherical Titanium Tank with No Propellant Management (PSI P/N 80182-1)
 - Tank MEOP = 600 psig.
 - Tank Volume = 61.9 liters
- Subsystem Dry Mass = 25.4 kg.
- Propellant Load Capacity = 137 kg.
- ΔV = 1430 m/s for Ms/c = 145 kg.

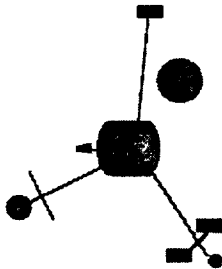


Subsystem Block Diagram

- Propulsion

LOCKHEED MARTIN



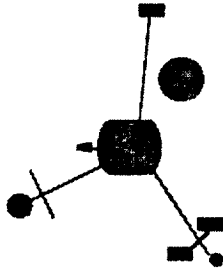


PHSL

LOCKHEED MARTIN

Propulsion

PROGRAM HARDWARE/SOFTWARE LIST (HARDWARE)			TITLE: Propulsion Subsystem			Ron King -61024			STATUS		CATEGORY		DATE: 28-Aug-95																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
PROGRAM OFFICE APPROVAL:			STATUS		SPEC NO.	DRAWING NO. /	NOMENCLATURE		D	QUANTITY PER CONTRACT			SEC	REMARKS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
			DESIGN	HOW			MAKE /	BUY		Q	R	F			S	TOT	CLASS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									



Subsystem Hardware List

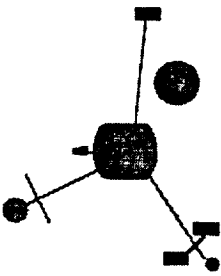
- Propulsion

LOCKHEED MARTIN



WBS #	ITEM #	Component	Source	Heritage	Qty	Size (L x W X H, cm) or (D x L, cm)	Mass (kg)	Max Power (W)	Reliability
2.1.11	1	Engines	Olin	MR-106E	6	6.6 D x 19	3.60	19.80	0.999
2.1.11	2	Tanks	PSI	80182-1	3	56.2 D x 56.2	15.70	-	
2.1.11	3	Filter	Brunswick	15267-642-2	1	4 D x 8	0.50	-	0.999
2.1.11	4	Fill/Drain Valve	MOOG	50E740	2	3 D x 6	0.20	-	0.993
2.1.11	5	Pressure Transducer	Psi-Tronics	631314-10	1	5 x 5 x 14	0.35	-	1.000
2.1.11	6	Brackets	LMSC	-			3.60	-	0.999
2.1.11	7	Lines	LMSC	-			1.40	-	0.999

Total = 25.4



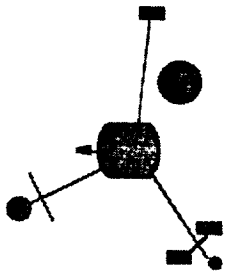
- Propulsion

Heritage/Background

LOCKHEED MARTIN



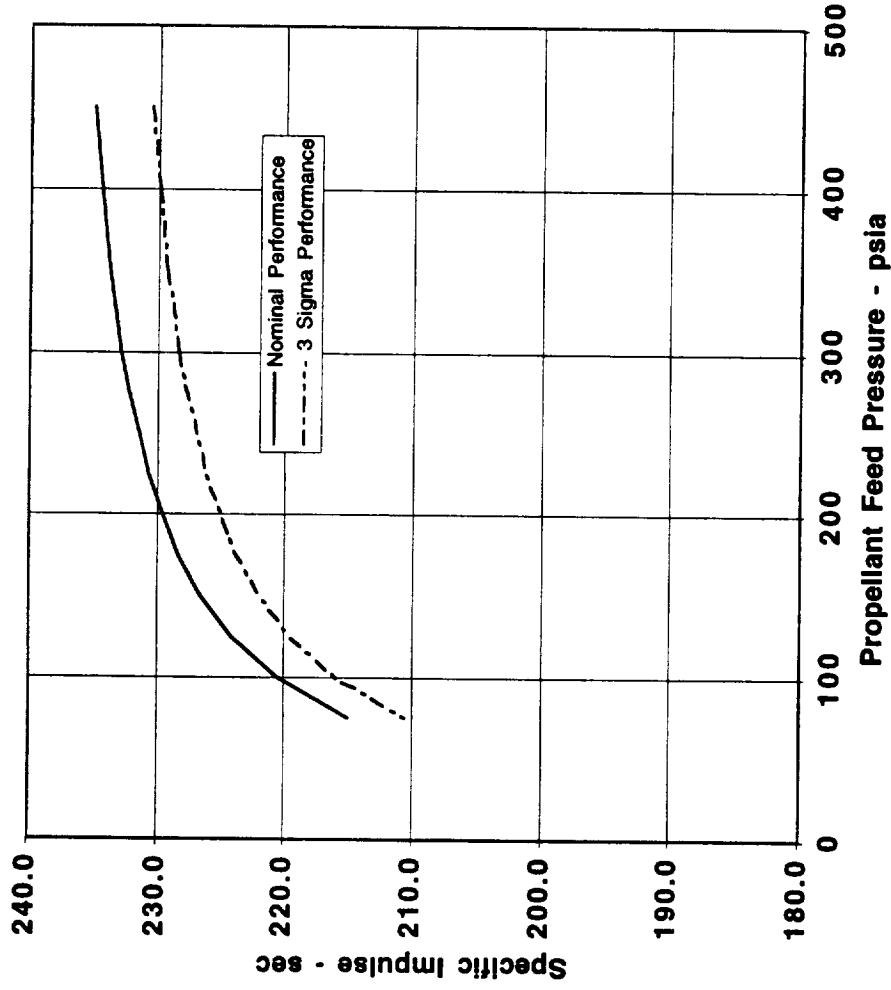
COMPONENTS	KEY REQUIREMENTS	HERITAGE	QUALIFICATION LEVELS
Thruster	Total Impulse = 65,800 N-s (87,750 N-s for thruster out condition)	Titan/Centaur GPS-IIR PAM-S	124,500 N-s
	Random Vibration = 25.5 grms Overall		28.1 grms Overall
Tank	Maximum Expected Operating Pressure = 500 psia	DSP	600 psig.
	Required Propellant Load w/ 28% Contingency = 50.6 kg Hydrazine		Burst Pressure = 1200 psig 52 kg Hydrazine (Minimum)
	Random Vibration = 17.4 grms Overall		19.5 grms Overall



Thruster Characteristics

- Propulsion

LOCKHEED MARTIN



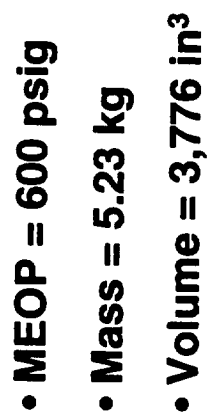
- Thruster Qualified for GPS
- Pulse Mode Operation - 0.016 sec to Steady State
- Minimum Impulse - 0.35 N-s @ 250 psia
- Total Impulse
 - 119,700 N-s @ 12,400 pulses
 - 124,500 N-s @ 186 pulses

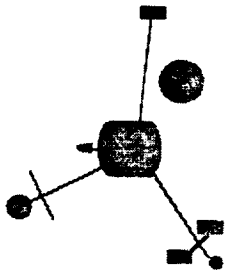




Propulsion

LOCKHEED MARTIN

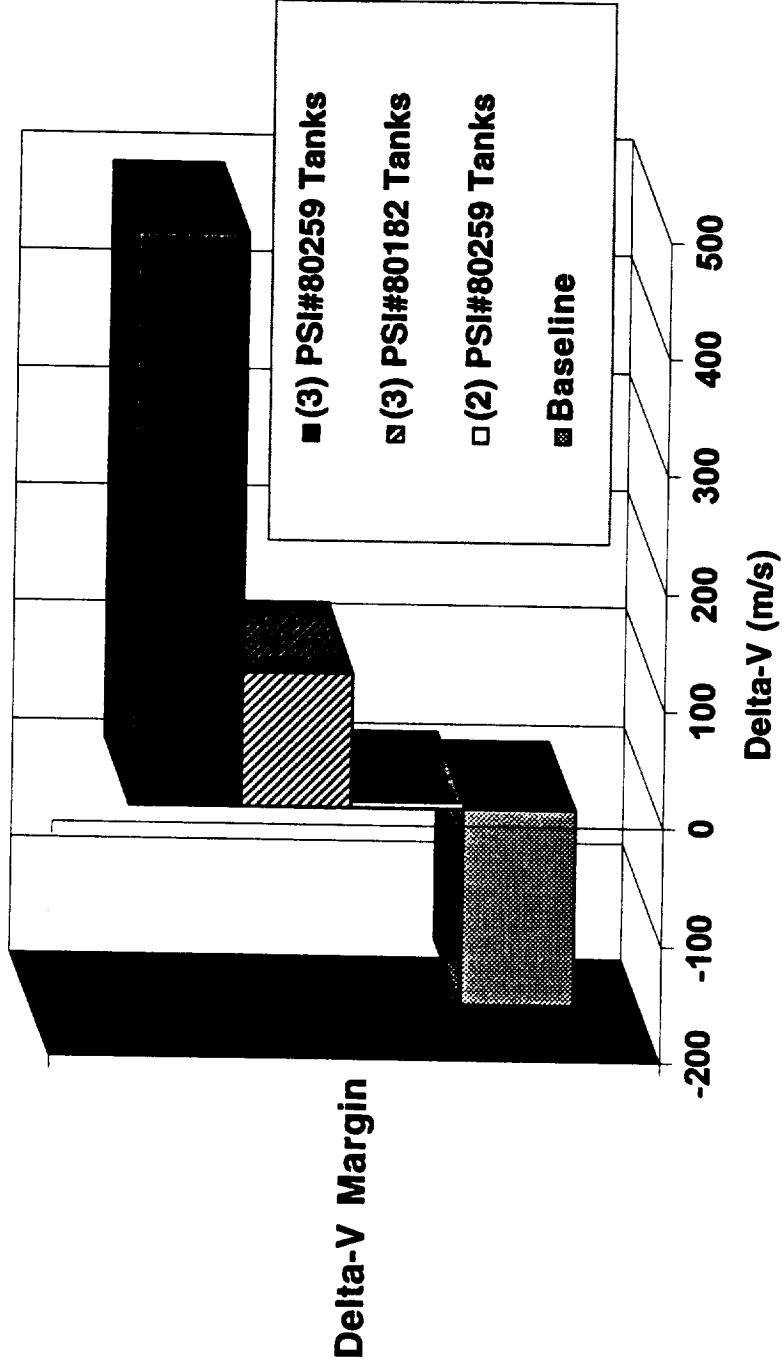


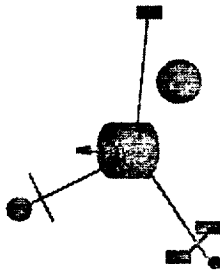


Tank Configuration Trades Performance Comparison

Propulsion

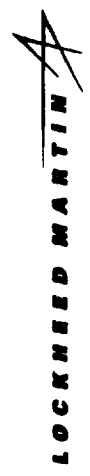
LOCKHEED MARTIN



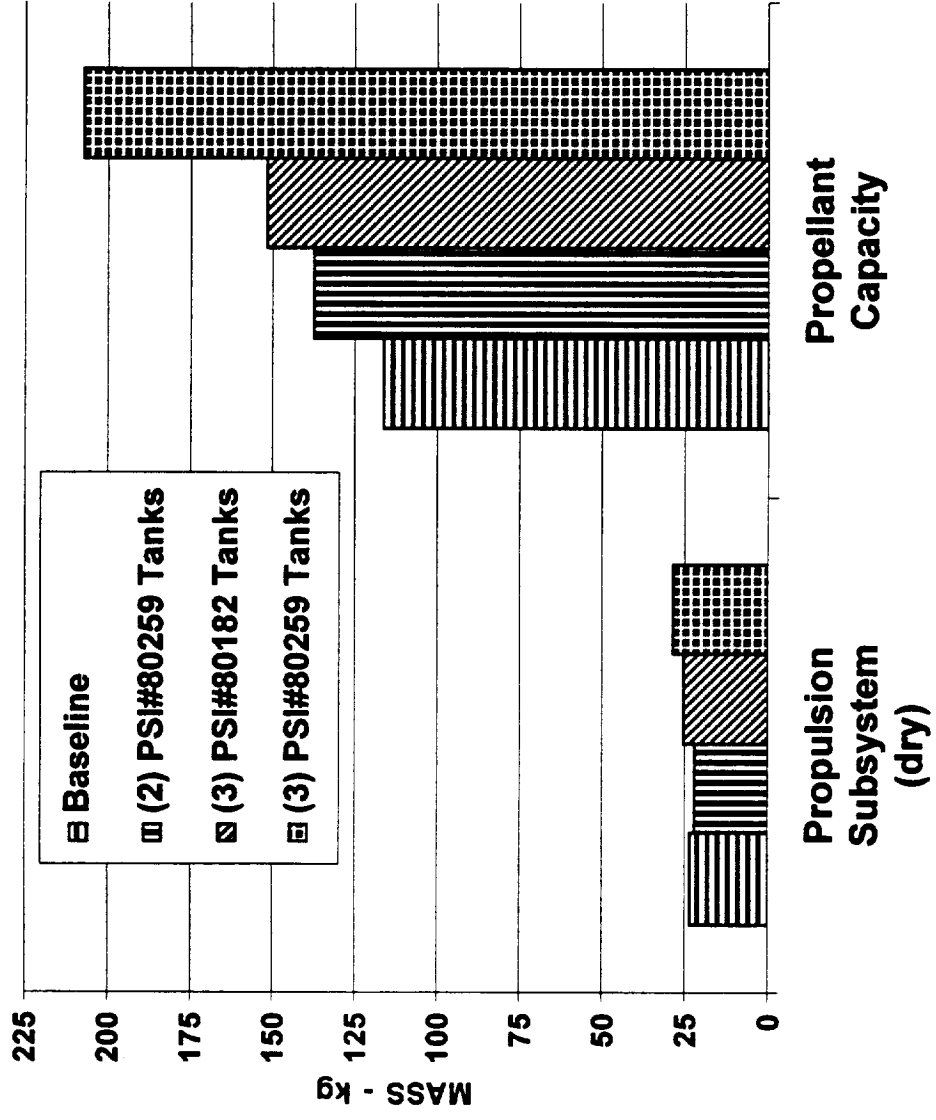


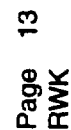
Tank Configuration Trades

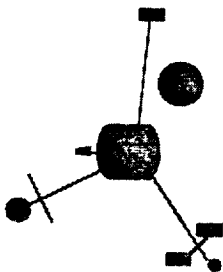
Mass Comparison



Propulsion







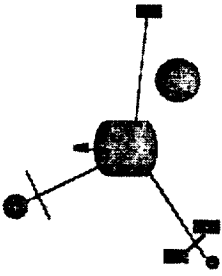
- Propulsion

Phase C/D Testing

LOCKHEED MARTIN



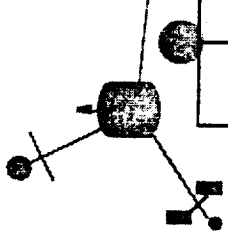
PROPULSION SUBSYSTEM TEST PROGRAM																								
Qualification Test Program												Acceptance Test Program												
	Functional	Ran Vib	sine Vib	Acoustic	Mech Shock	Thermal Cycle	Thermal Vac	Proof/Burst	Leak	EMC	Life	Wt.	Functional	Ran Vib	sine Vib	Acoustic	Mech Shock	Thermal Cycle	Thermal Vac	Proof	Leak	EMC	Life	Wt
														T	T					T	T			
Thrusters																								
Fill & Drain Valves														T						T	T			T
Propellant Tank															T					T	T			T
Filter														T						T	T			T
Press Transducers														T	T			T		T	T			T
Lines & Brackets																		T		T	T			
Subsystem Ass'y														T						T	T			



Residuals

LOCKHEED MARTIN

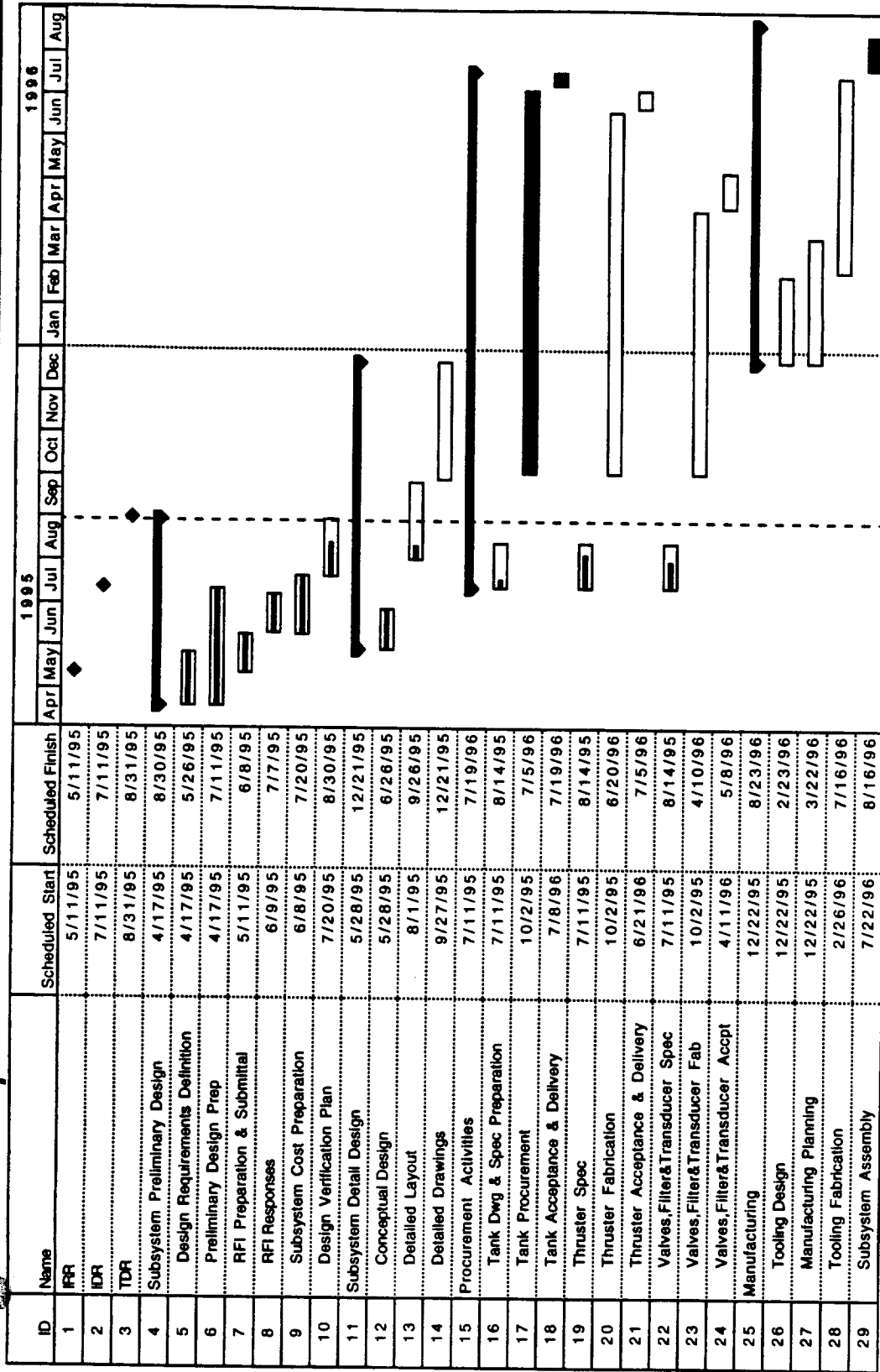
- **Current Design Results in a Residual Propellant Load of 56.8 kg.
at the End of the Mission**
- **The Residual Propellant is Equivalent to an Additional 355 m/s
Delta-V Capability for the 145 kg Spacecraft**
- **Or an Additional 2.9 Years Operation at the 100 km Orbit**

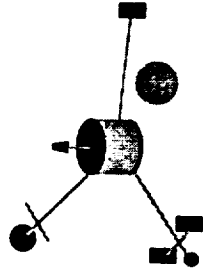


Schedule

Propulsion

LOCKHEED MARTIN



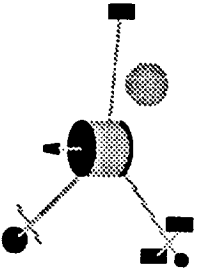


-Avionics

Avionics Subsystems

Communications and Tracking
Command and Data Handling
Attitude Control and Stabilization

Gerry Grismore

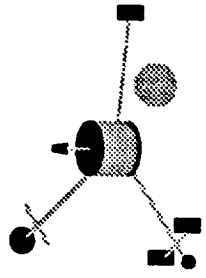


Avionics

LOCKHEED MARTIN

Functions

- Communications and Tracking
 - Support Two-Way Turn-around Doppler tracking
 - Acquire Forward Link
 - Demodulate command data stream
 - Deliver Return Link
 - Accept Telemetry
 - Viterbi encode (Rate 1/2 constraint length 7)
 - Modulate onto subcarrier
- Command and Data Handling
 - Acquire, Multiplex, Store and Deliver Downlink Telemetry
 - Accept, Decode, Route and Execute Uplink Commands
 - Maintain System Synchronization
- Attitude Control and Stabilization
 - Provide Sun and Moon observation data for attitude determination
 - Provide passive nutation damping



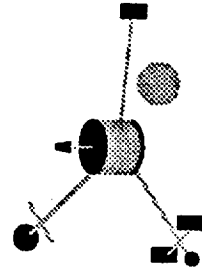
Key Requirements and Objectives

Trans-Lunar Cruise Phase

Avionics

LOCKHEED MARTIN

- Accept and Execute Uplink Commands
 - System Turn-on and Initialization
 - Decrease Spin Rate (60 to 12 (TBR))
 - Re-orient to Cruise Attitude
 - Boom Deployment
 - Spin up to normal rate (2 (TBR) to 12 rpm)
 - Provide Downlink Telemetry
 - Support Attitude Determination
 - Support SI Sensor Calibrations
 - Orbit Injection
 - Re-orient to Injection Attitude
 - Decrease velocity to capture orbit
 - Adjust altitude to mapping orbit (100 Km circular)
 - Re-orient to mapping attitude
- Provide Engineering and Normal Telemetry
 - Support Attitude Determination and Control



-Avionics

Key Requirements and Objectives

Mapping Support Phase

LOCKHEED MARTIN

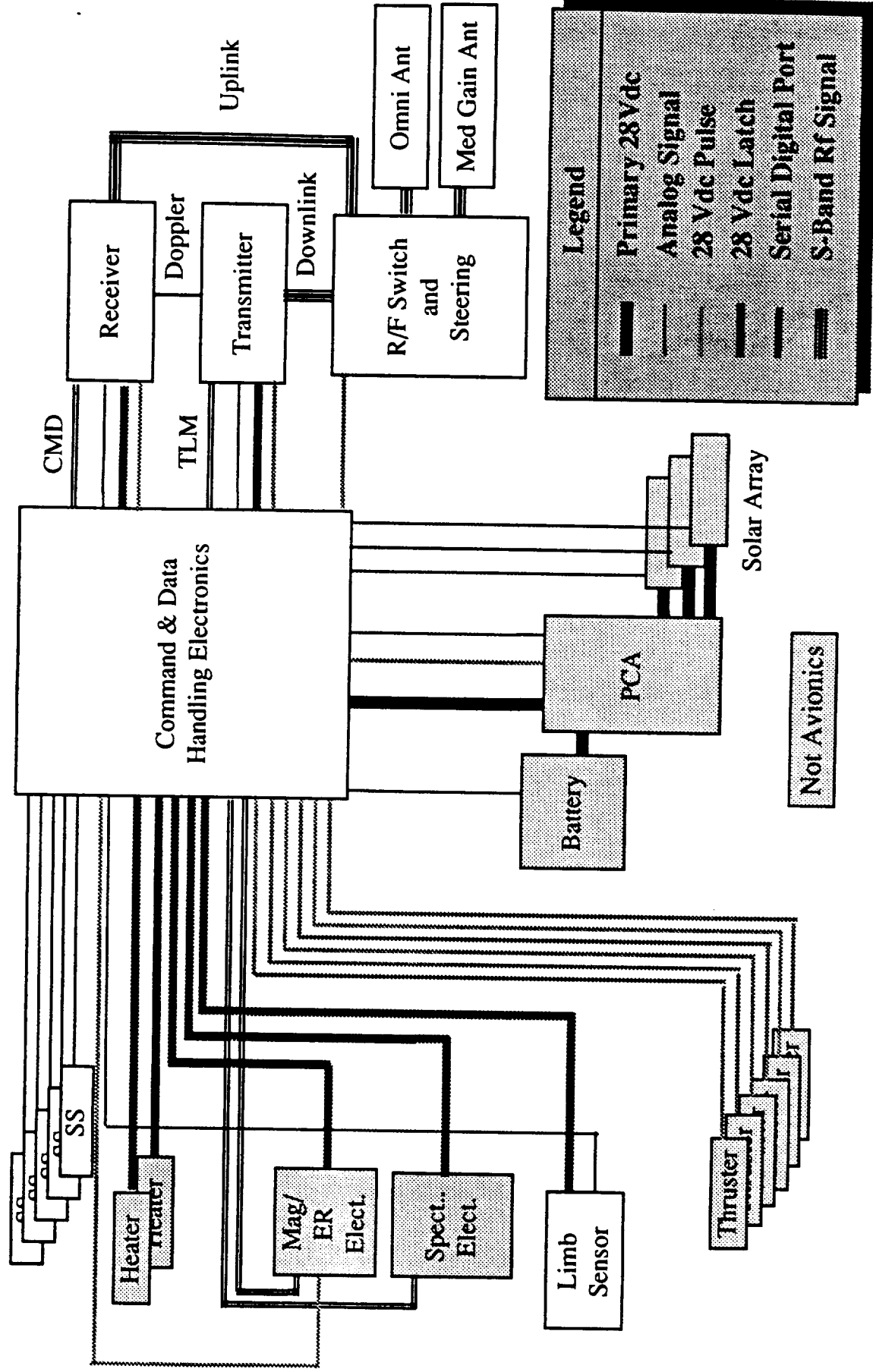


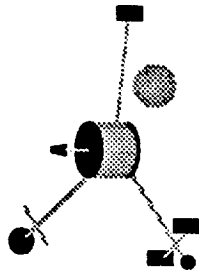
- Provide operational Command and Telemetry
 - Engineering Only Mode (300 bps)
 - Spacecraft Health and Status
 - Support Attitude Determination and Control
 - Normal Operations Mode (3600 bps)
 - Provide continuous Science Data
 - Include Engineering Data
 - Support Attitude and Orbit Control
- Tolerate Occultation (3200 second retransmission)

Lunar Prospector Spacecraft Overview

Avionics

LOCKHEED MARTIN





-Avionics

LOCKHEED MARTIN

Design

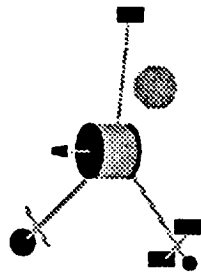
- Communications and Tracking
 - LORAL CXS-600B STDN Transponder
 - S-Band Antenna System
 - Helix Medium Gain Antenna -- 6 db Gain ($10^{\circ} \times 360^{\circ}$)
 - Omni Antenna -- 0 db Gain (hemisphere)
 - Switching and Routing Electronics (RF Cables, diplexer and switch)
- Command and Data Handling
 - Multi-Function Electronics
 - Command Accept, Decode, Execute
 - Telemetry Signal Sampling, A/D Conversion
 - Telemetry Formatting, Storage, and Distribution
 - Attitude Sensor crossing time determination
- Attitude Control and Stabilization
 - 5 Dual Slit Adcole Sun Sensors
 - Barnes Earth/Moon Limb Crossing Sensor
 - LMMS Passive Ball in Tube Nutation Damper



■ Avionics

LOCKHEED MARTIN

2



Avionics

Equipment Characteristics

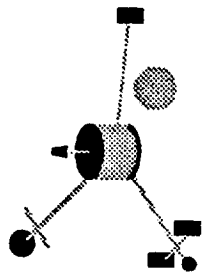
LOCKHEED MARTIN



ITEM #	WBS #	Component	Source	Heritage	Quantity	Size (cm) (LxWXH) or (DxH)	Mass (kg)	Power (W)	Reliability
1	2.1.8	TRANSPONDER	LORAL	CXS-600B	1	22x14x15	3.90	37.8	0.97
2	2.1.8	S-BAND ANTENNA SYSTEM	LMMS			18x80	2.40		1.00
2.1	2.1.8	MEDIUM GAIN ANTENNA	LMMS	3P16630	1		2.00		1.00
2.2	2.1.8	LOW GAIN ANTENNA	LMMS	8539867	1		0.40		1.00
3	2.1.8	SWITCHING AND ROUTING ELECTRONICS	TBD	TBD	1		0.70		1.00
1	2.1.9	COMMAND AND DATA HANDLING ELECTRONICS	TBD	TBD	1	24x24x10	3.00	10.0	0.95
1	2.1.10	SUN SENSOR ASSEMBLY	LMMS		1	10x2.5x2.5	1.25		
1.1		SUN SENSOR	ADCOLE	21175	5	1.2x2.5x1.5	0.15		0.99
1.2		MOUNT	LMMS		1		0.50		
2	2.1.10	LIMB CROSSING SENSOR	BARNES	13-210B	1	7x11.4	0.80	1.0	0.99
3	2.1.10	NUTATION DAMPER	LMMS	3P11056	1	30x10x5	1.00		1.00

Total

13.05 48.8 0.90

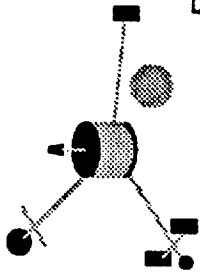


-Avionics

LOCKHEED MARTIN



Communications Functions



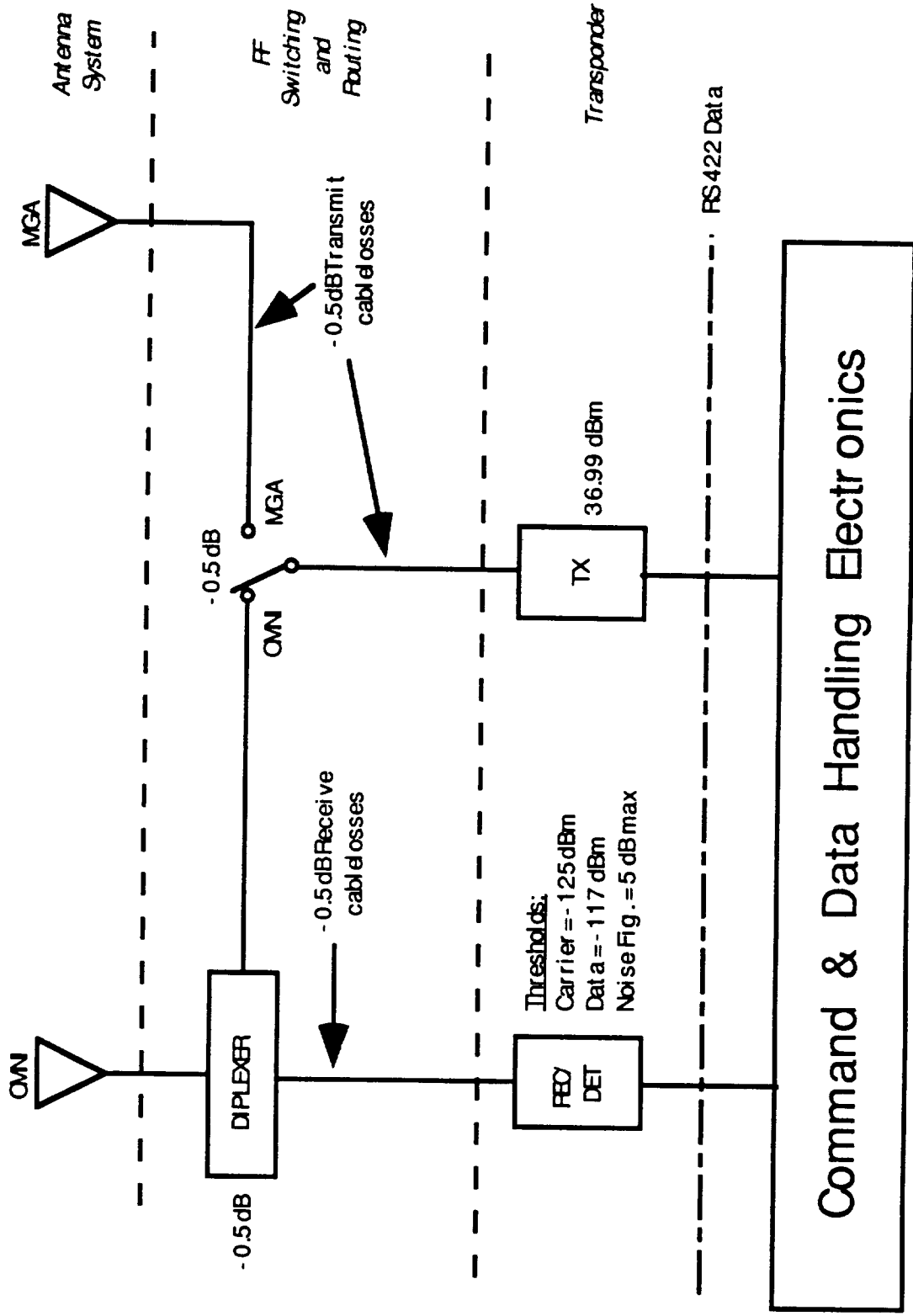
Communications Overview

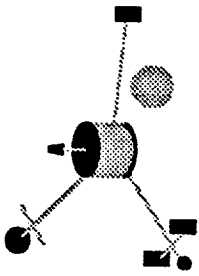
Avionics

ERP = 35.99 dBm (max)

ERP = 41.99 dBm (min)

LOCKNEED MARTIN





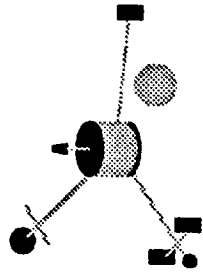
Avionics

Communications Issues

LOCKHEED MARTIN

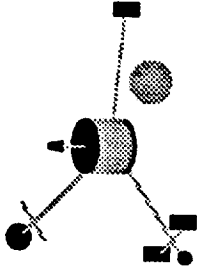


- Transponder Frequency Definition
 - Need Definition by 1 October
 - Establishes Requirements for Transponder components



-Avionics

Command and Data Handling Functions

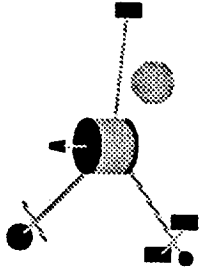


C&DH Interface Definitions

Avionics

LOCKHEED MARTIN

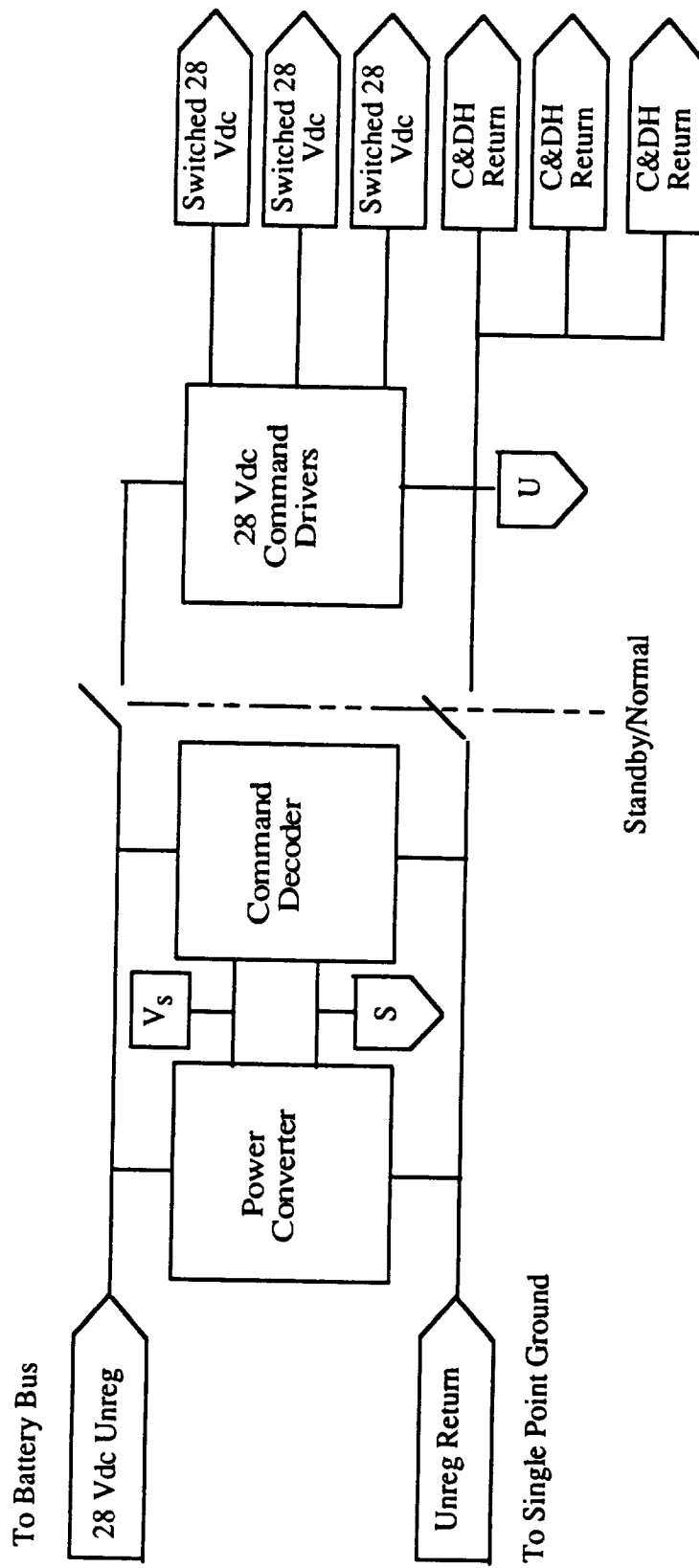
- Switched 28 Vdc Signals
 - 28 Vdc Power Distribution Latches
 - Turn On and Turn Off by Real-Time Command
 - 28 Vdc Discrete Commands (Valves, Pyros, etc.).
 - Turn On for duration of Real-Time Command
 - Minimum duration 100 ms (TBR)
 - Rise/Fall times (10% to 90%) nominally 1 ms.
- Analog Signals (8 bit A/D converted for Telemetry output)
 - Passive Resistance independantly conditioned to active 0-5.12 Vdc
 - Active 0-5.12 Vdc
 - Source Impedance -- 5 Kohms maximum
 - Load Impedance -- 100 Kohms (TBR) minimum
- 5 Vdc Discrete Signals
 - Unipolar 5 Vdc Logic Levels
 - Status Monitors, Strokes, Gates, Clocks, Serial Data
 - Positive True Sense

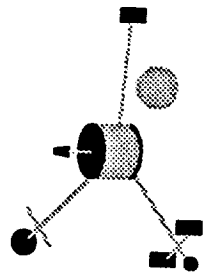


28 VDC Command Distribution

Avionics

LOCKHEED MARTIN

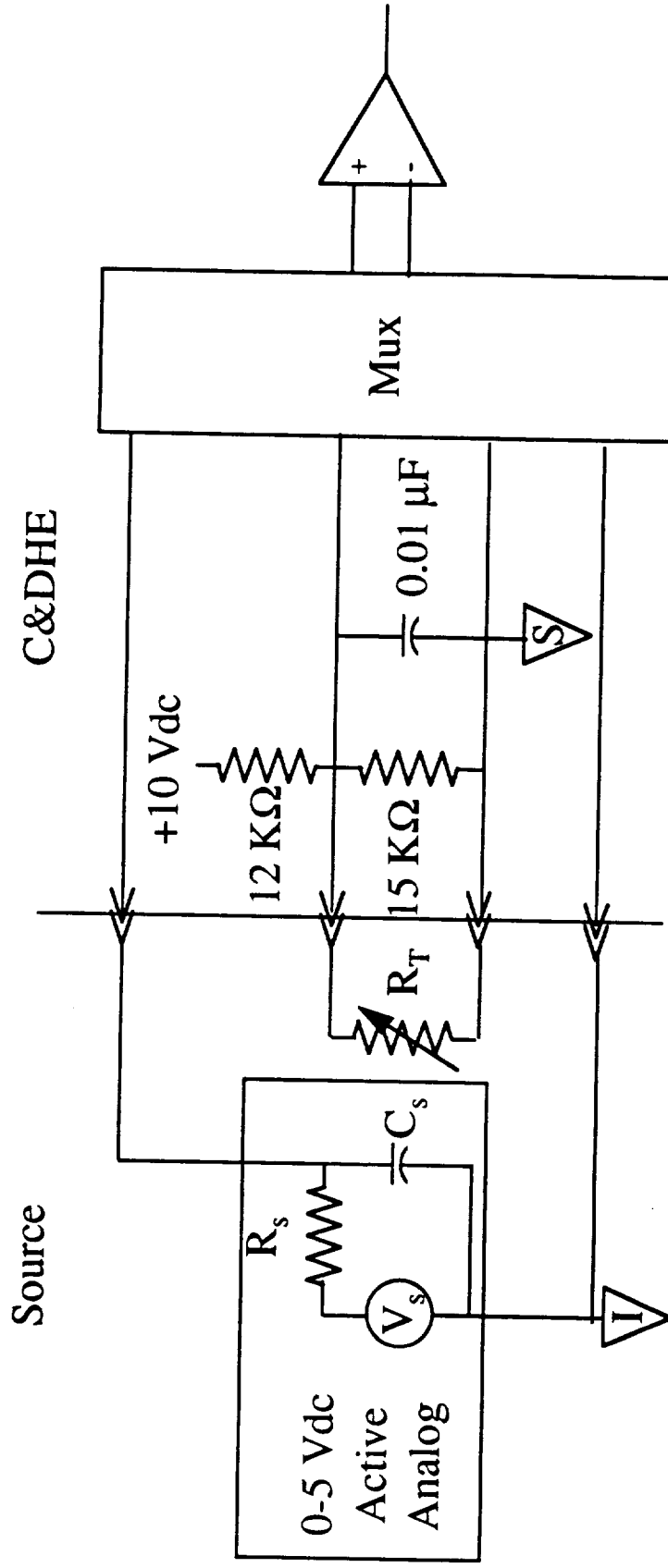


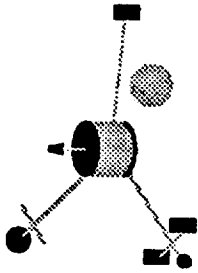


Analog Telemetry Interfaces (Typical)

Avionics

LOCKHEED MARTIN



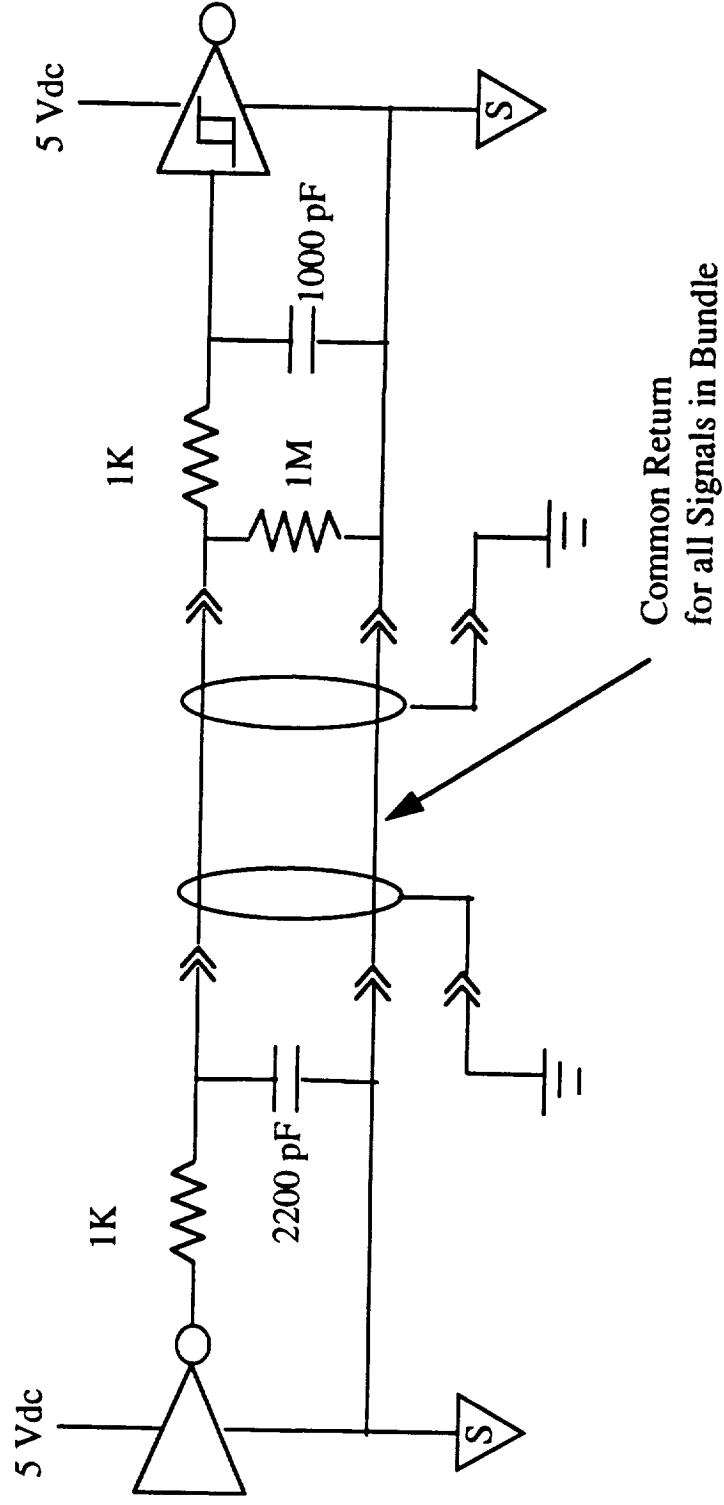


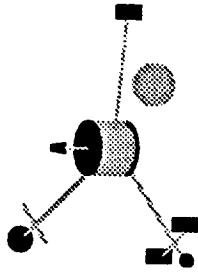
Avionics

Discrete Signal Interfaces

LOCKHEED MARTIN

Drivers are 54HC244 or equivalent
Receivers are 54HC14 or equivalent





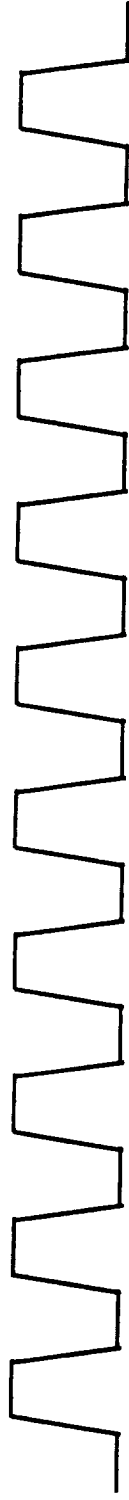
Serial Transfer Timing

Avionics

LOCKHEED MARTIN



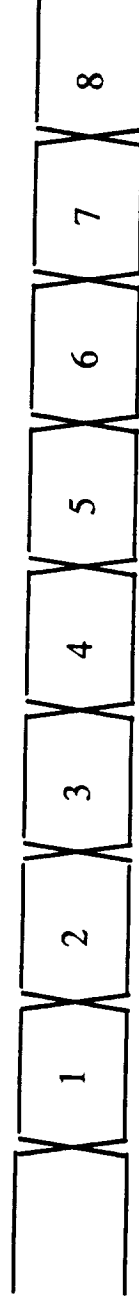
Clock



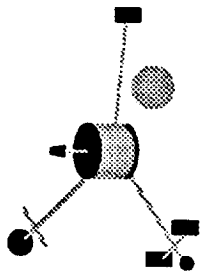
Gate



Data



Shows 8 bit byte transfer, actual length is application dependant
Bit Numbering within transfer byte is as shown (continues for longer words)
Data is presented MSB first (where applicable) by convention
Incompatibility between Gate Duration and Data size is an error condition
Next data word transfer will normally commence at next Gate enable.

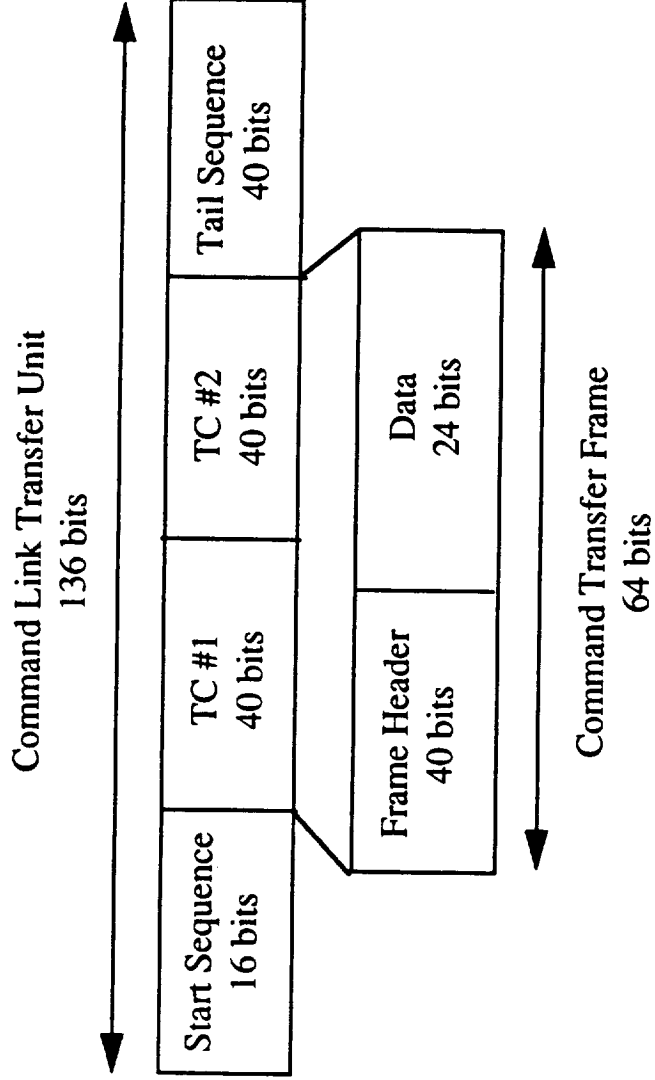


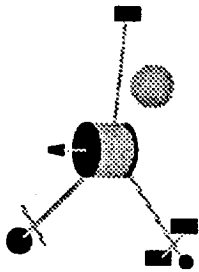
Uplink Command Structure

-Avionics

LOCKHEED MARTIN

40 bit BCH(56,63) Encoded Telecommand Code Blocks
(32 data bits per CodeBlock)

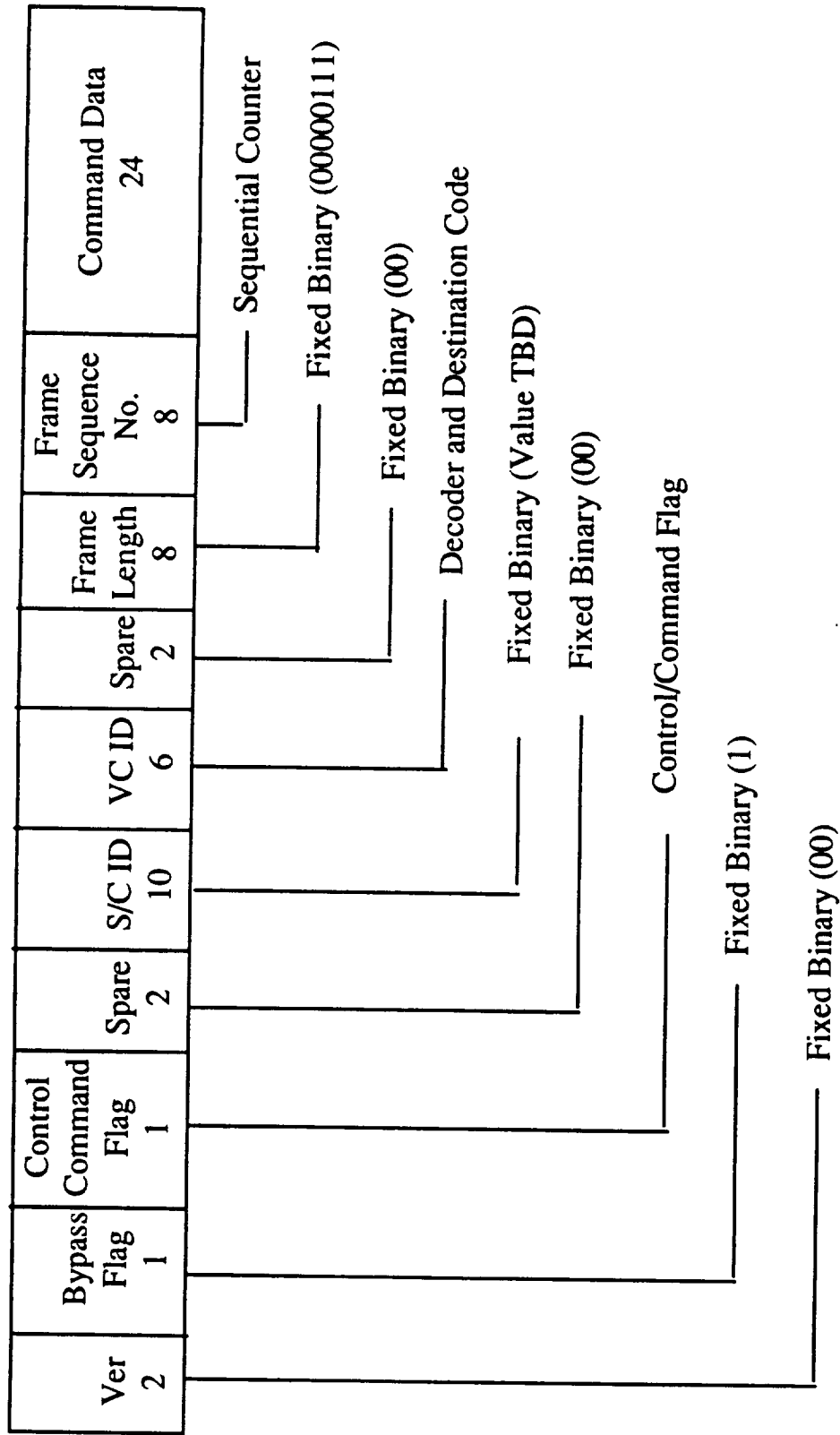


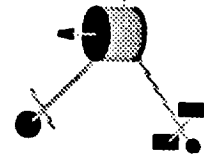


Command Transfer Frame Structure

Avionics

LOCKHEED MARTIN



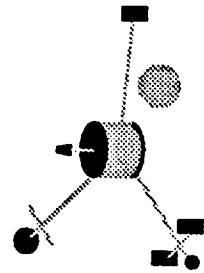


28 Vdc Command Signal Interfaces (1 of 2)

Avionics

LOCKHEED MARTIN

Subsystem	Command Name	Source	Destination	Type	Comment
Communications	Coherent Mode Override	C&DHE	Xpndr	28 VDC Latch	C&DHE Unreg Return
Communications	Encoder Enable	C&DHE	Xpndr	28 VDC Latch	C&DHE Unreg Return
Communications	Ranging On	C&DHE	Xpndr	28 VDC Latch	C&DHE Unreg Return
Communications	Receiver Power	C&DHE	Xpndr	28 VDC	C&DHE Unreg Return
Communications	SOOn	C&DHE	Xpndr	28 VDC Latch	C&DHE Unreg Return
Communications	Transmitter On	C&DHE	Xpndr	28 VDC Latch	C&DHE Unreg Return
Communications	Transmitter Power	C&DHE	Xpndr	28 VDC Latch	C&DHE Unreg Return
Communications	Xmir to MGA	C&DHE	RF Switch	28 VDC Latch	C&DHE Unreg Return
Communications	Xmir to Omni	C&DHE	RF Switch	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Batt #1 Chg Control, Pri	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Batt #1 Chg Control, Red	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Batt #1 Current Monitor Pwr	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Batt #1 Full Charge	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Batt #1 Trickle Charge	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Batt #2 Chg Control, Pri	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Batt #2 Chg Control, Red	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Batt #2 Current Monitor Pwr	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Batt #2 Full Charge	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Batt #2 Trickle Charge	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Battery #1 VT Level #1 Select	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Battery #1 VT Level #2 Select	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Battery #2 VT Level #1 Select	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Battery #2 VT Level #2 Select	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Disable LVCO #1	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Disable LVCO #2	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	LVCO Override	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	S/A Current Monitor Pwr	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	S/A Terminate	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	S/A Terminate Off	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Select LVCO #1	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return
Electrical Power	Select LVCO #2	C&DHE	PCA	28 VDC Latch	C&DHE Unreg Return

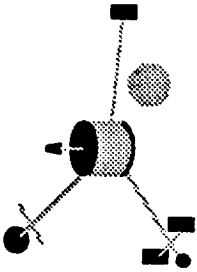


Avionics

28 Vdc Command Signal Interfaces (2 of 2)

LOCKHEED MARTIN

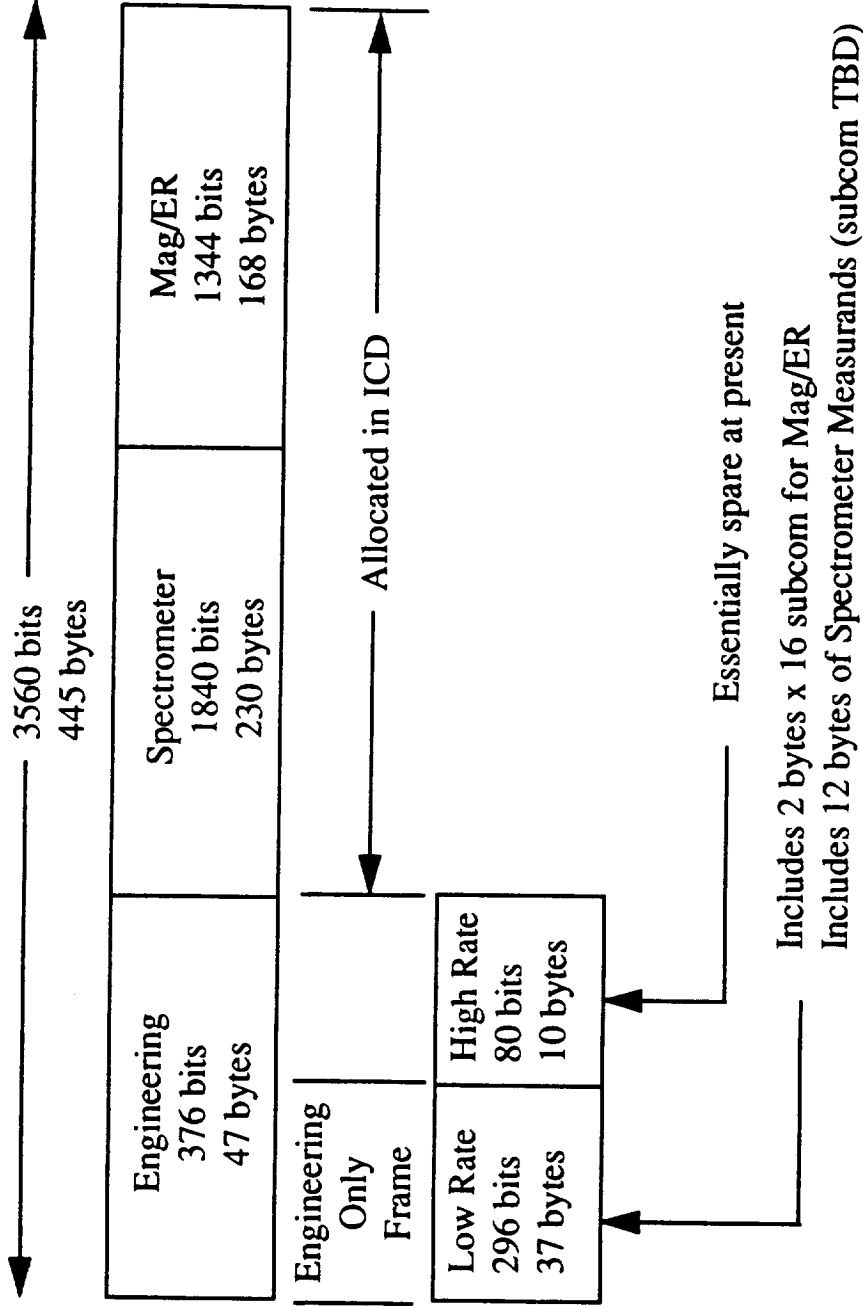
Subsystem	Command Name	Source	Destination	Type	Comment
Mag/ER	28 VDC Heater Power A	C&DHE	Mag/ER	28 VDC Latch	Heater Power Return
Mag/ER	28 VDC Heater Power B	C&DHE	Mag/ER	28 VDC Latch	C&DH Unreg Return
Mag/ER	28 VDC Power A	C&DHE	Mag/ER	28 VDC Latch	C&DH Unreg Return
Mag/ER	28 VDC Power B	C&DHE	Mag/ER	28 VDC Latch	C&DH Unreg Return
Mag/ER	ER Cover Open A	C&DHE	Mag/ER	28 VDC Latch	C&DH Unreg Return
Mag/ER	ER Cover Open B	C&DHE	Mag/ER	28 VDC Latch	C&DH Unreg Return
Mechanisms	Pin Puller #1	C&DHE	Pin Puller #1	28 VDC Latch	C&DH Unreg Return
Mechanisms	Pin Puller #2	C&DHE	Pin Puller #2	28 VDC Latch	C&DH Unreg Return
Propulsion	Pressure XDCR Power	C&DHE	Pressure XDCR	28 VDC Latch	XDCR Return
Propulsion	Thruster #1 Cat Bed Heater	C&DHE	Thruster #1	28 VDC Latch	Heater Return
Propulsion	Thruster #1 Fire A&B	C&DHE	Thruster #1	28 VDC Latch	Fire Return
Propulsion	Thruster #2 Cat Bed Heater	C&DHE	Thruster #2	28 VDC Latch	Heater Return
Propulsion	Thruster #2 Fire A&B	C&DHE	Thruster #2	28 VDC Latch	Fire Return
Propulsion	Thruster #3 Cat Bed Heater	C&DHE	Thruster #3	28 VDC Latch	Heater Return
Propulsion	Thruster #3 Fire A&B	C&DHE	Thruster #3	28 VDC Latch	Fire Return
Propulsion	Thruster #4 Cat Bed Heater	C&DHE	Thruster #4	28 VDC Latch	Heater Return
Propulsion	Thruster #4 Fire A&B	C&DHE	Thruster #4	28 VDC Latch	Fire Return
Propulsion	Thruster #5 Cat Bed Heater	C&DHE	Thruster #5	28 VDC Latch	Heater Return
Propulsion	Thruster #5 Fire A&B	C&DHE	Thruster #5	28 VDC Latch	Fire Return
Propulsion	Thruster #6 Cat Bed Heater	C&DHE	Thruster #6	28 VDC Latch	Heater Return
Propulsion	Thruster #6 Fire A&B	C&DHE	Thruster #6	28 VDC Latch	Fire Return
Spectrometer	28 VDC Power	C&DHE	Spec Electr	28 VDC Latch	C&DH Unreg Return
Spectrometer	APS Sensor On	C&DHE	Spec Electr	28 VDC Latch	C&DH Unreg Return
Spectrometer	GRS Sensor On	C&DHE	Spec Electr	28 VDC Latch	C&DH Unreg Return
Spectrometer	NS Sensor On	C&DHE	Spec Electr	28 VDC Latch	C&DH Unreg Return
Spectrometer	Sensors Off	C&DHE	Spec Electr	28 VDC Latch	C&DH Unreg Return
Thermal	Primary Heater Bus	C&DHE	48 Thermostats	28 VDC Latch	Heater Return
Thermal	Redundant Heater Bus	C&DHE	48 Thermostats	28 VDC Latch	Heater Return

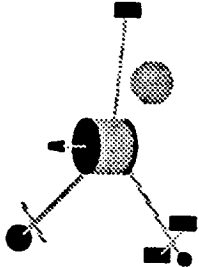


Telemetry Frame Structure

Avionics

LOCKHEED MARTIN





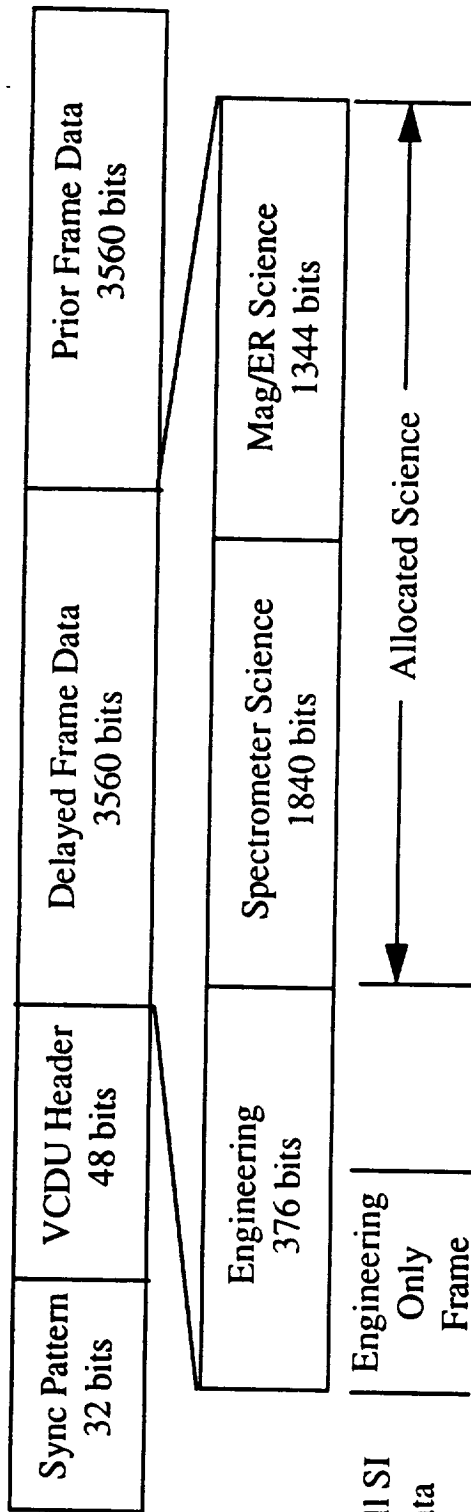
Telemetry Output Formats

-Avionics

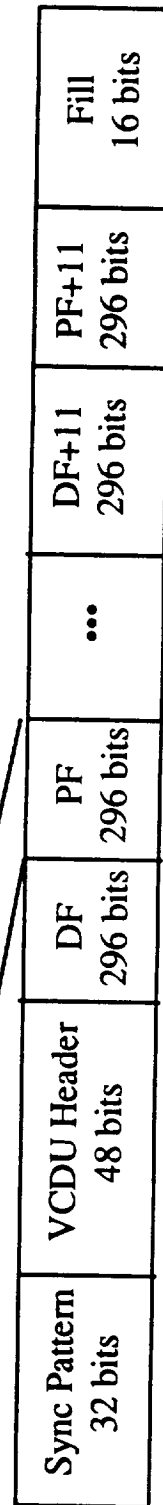
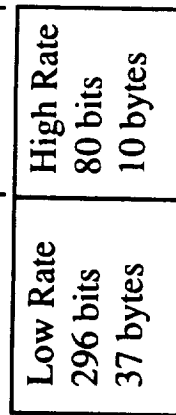
LOCKHEED MARTIN

Science Data Format

2 sec @ 3600 bps



Includes all SI Analog Data

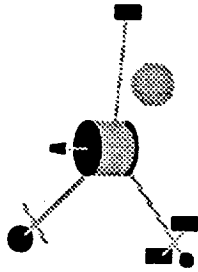


24 sec @ 300 bps

Engineering Data Format

23

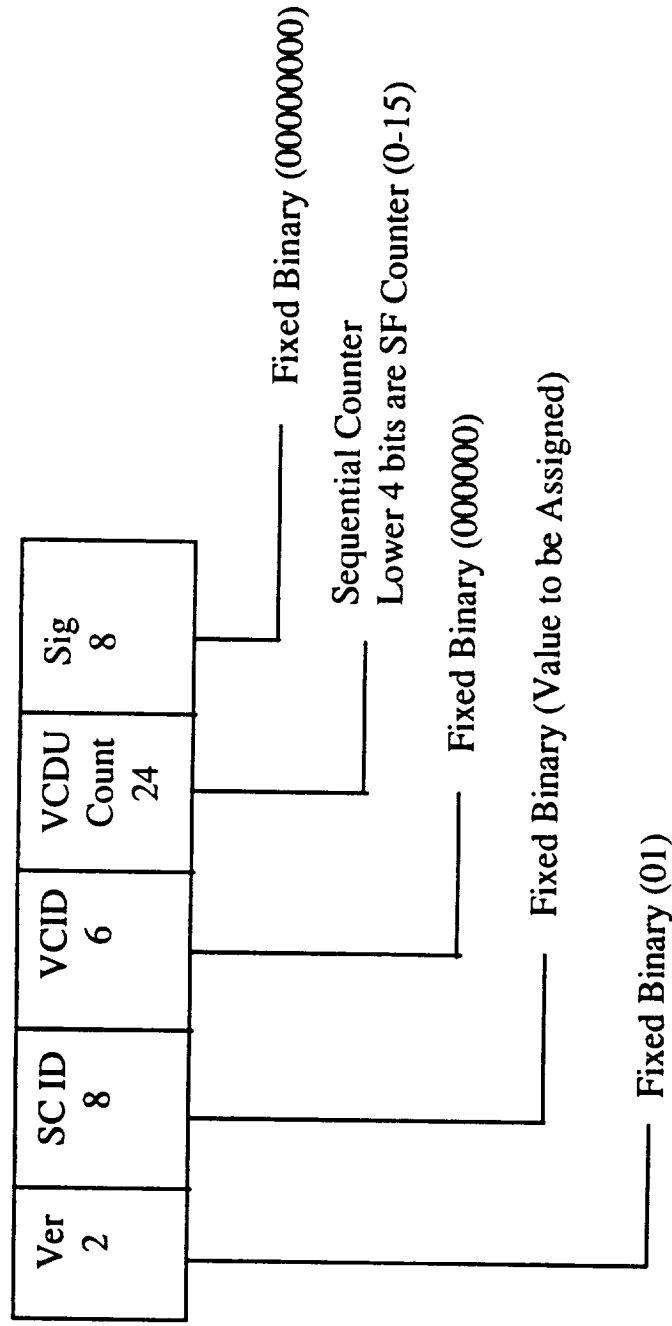
GG 8/30/95



VCDU Header Structure

Avionics

LOCKHEED MARTIN



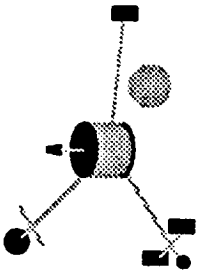
Note: For Engineering mode VCDU advances by 12 for sequential transmissions

Analog Telemetry Signal Interfaces (2 of 2)

Avionics

LOCKHEED MARTIN

Subsystem	Command Name	Source	Destination	Type	Comment
Mag/ER	Analog Mux A	Mag/ER	C&DHE	5 Vdc Analog	Analog Mux Return A
Mechanisms	Boom 1 Deploy	Boom 1 Sw	C&DHE	Switch Closure	Tentative (TBR)
Mechanisms	Boom 2 Deploy	Boom 2 Sw	C&DHE	Switch Closure	Tentative (TBR)
Mechanisms	Boom 3 Deploy	Boom 2 Sw	C&DHE	Switch Closure	Tentative (TBR)
Propulsion	Pressure	Pressure XDCR	C&DHE	5 Vdc Analog	XDCR Signal Rtn
Propulsion	Thruster #1 Cat Bed TC	Thruster #1 TC	C&DHE	Passive Analog	
Propulsion	Thruster #2 Cat Bed TC	Thruster #2 TC	C&DHE	Passive Analog	
Propulsion	Thruster #3 Cat Bed TC	Thruster #3 TC	C&DHE	Passive Analog	
Propulsion	Thruster #4 Cat Bed TC	Thruster #4 TC	C&DHE	Passive Analog	
Propulsion	Thruster #5 Cat Bed TC	Thruster #5 TC	C&DHE	Passive Analog	
Propulsion	Thruster #6 Cat Bed TC	Thruster #6 TC	C&DHE	Passive Analog	
Propulsion and Thermal	Tank 1 Temp	Thermistor 1	C&DHE	Passive Analog	Thermistor 1 Return
Propulsion and Thermal	Tank 2 Temp	Thermistor 2	C&DHE	Passive Analog	Thermistor 2 Return
Propulsion and Thermal	Tank 3 Temp	Thermistor 3	C&DHE	Passive Analog	Thermistor 3 Return
Spectrometer	Electronics +5 Vdc Voltage	Spec Electr	C&DHE	5 Vdc Analog	Instrumentation Return
Spectrometer	Electronics +12 Vdc Voltage	Spec Electr	C&DHE	5 Vdc Analog	Instrumentation Return
Spectrometer	GRS HV#1 Voltage	Spec Electr	C&DHE	5 Vdc Analog	Instrumentation Return
Spectrometer	GRS HV#2 Voltage	Spec Electr	C&DHE	5 Vdc Analog	Instrumentation Return
Spectrometer	NS HV#1 Voltage	Spec Electr	C&DHE	5 Vdc Analog	Instrumentation Return
Spectrometer	NS HV #2 Voltage	Spec Electr	C&DHE	5 Vdc Analog	Instrumentation Return
Spectrometer	APS -25VDC Voltage	Spec Electr	C&DHE	5 Vdc Analog	Instrumentation Return
Spectrometer	Electronics 28 VDC Current	Spec Electr	C&DHE	5 Vdc Analog	Instrumentation Return
Spectrometer and Thermal	Electronics Temperature	Spec Electr	C&DHE	Passive Analog	Temperature Return
Spectrometer and Thermal	GPS Temp	Thermistor 12	C&DHE	Passive Analog	Thermistor 12 Return
Spectrometer and Thermal	APS Temp	Thermistor 13	C&DHE	Passive Analog	Thermistor 13 Return
Spectrometer and Thermal	Neutron Spec Temp	Thermistor 14	C&DHE	Passive Analog	Thermistor 14 Return
Thermal	Spare	Thermistor 4	C&DHE	Passive Analog	Thermistor 4 Return
Thermal	Spare	Thermistor 5	C&DHE	Passive Analog	Thermistor 5 Return
Thermal	Spare	Thermistor 6	C&DHE	Passive Analog	Thermistor 6 Return
Thermal	Spare	Thermistor 9	C&DHE	Passive Analog	Thermistor 9 Return
Thermal	Spare	Thermistor 10	C&DHE	Passive Analog	Thermistor 10 Return
Thermal	Spare	Thermistor 15	C&DHE	Passive Analog	Thermistor 15 Return
Thermal	Spare	Thermistor 16	C&DHE	Passive Analog	Thermistor 16 Return

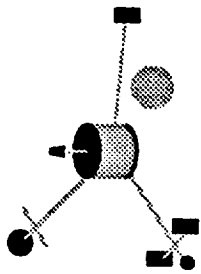


Avionics

LOCKHEED MARTIN



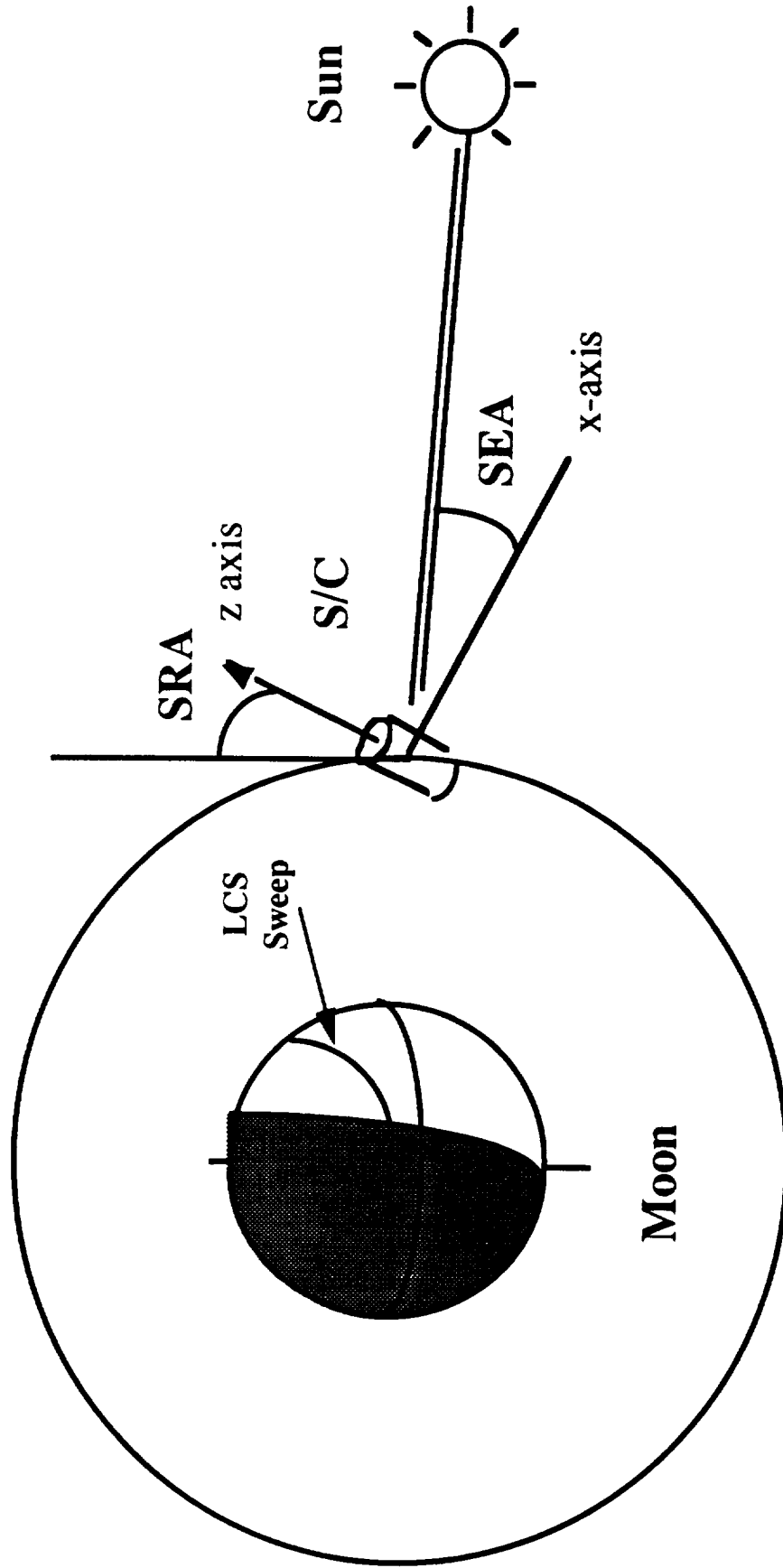
Attitude Control Functions

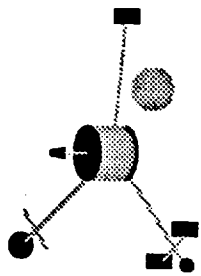


Lunar Prospector Orbital Geometry

-Avionics

LOCKHEED MARTIN

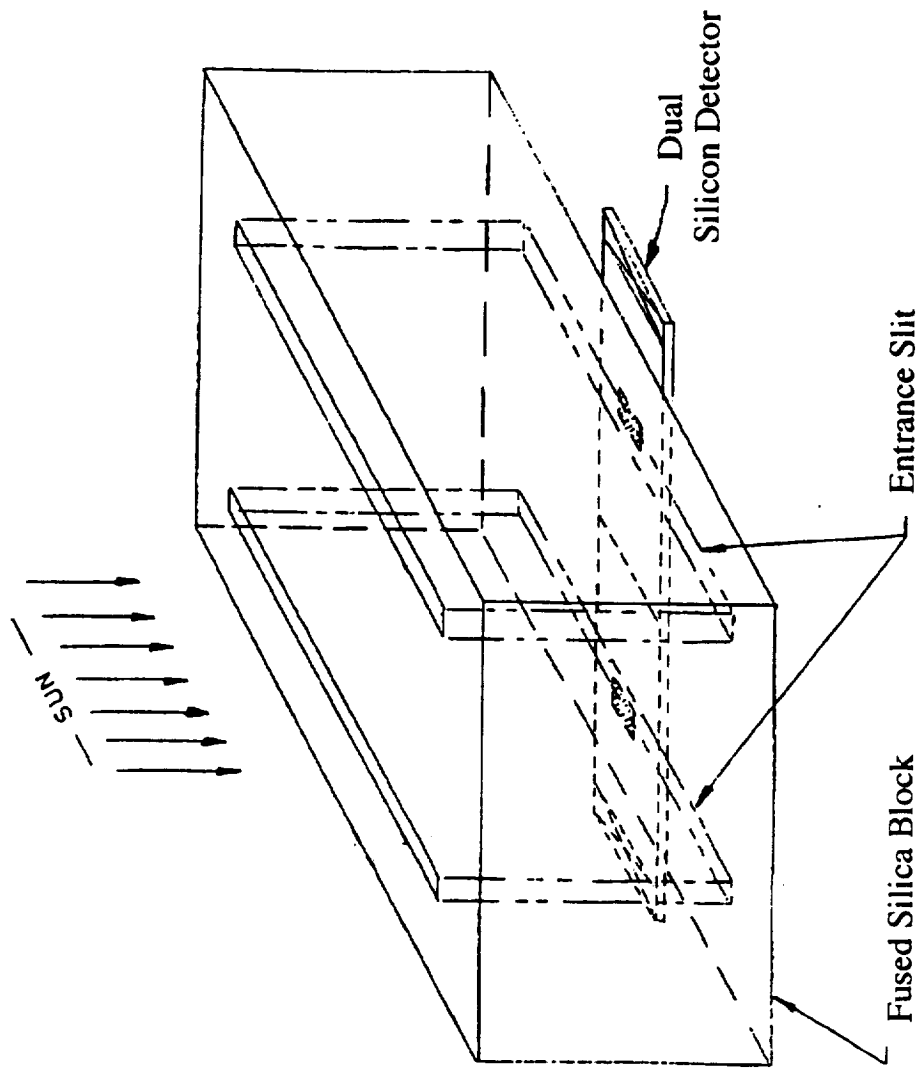


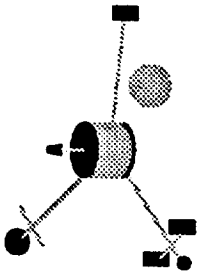


Sun Sensor Head Geometry

Avionics

LOCKHEED MARTIN





-Avionics

LOCKHEED MARTIN

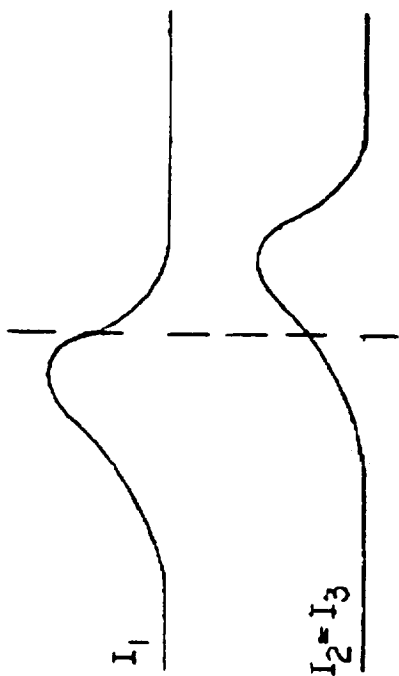


Detector Current vs. Time

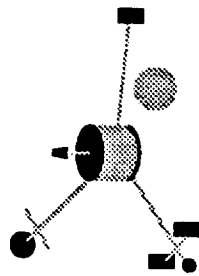
Sun Line

Leading Slit

Trailing Slit



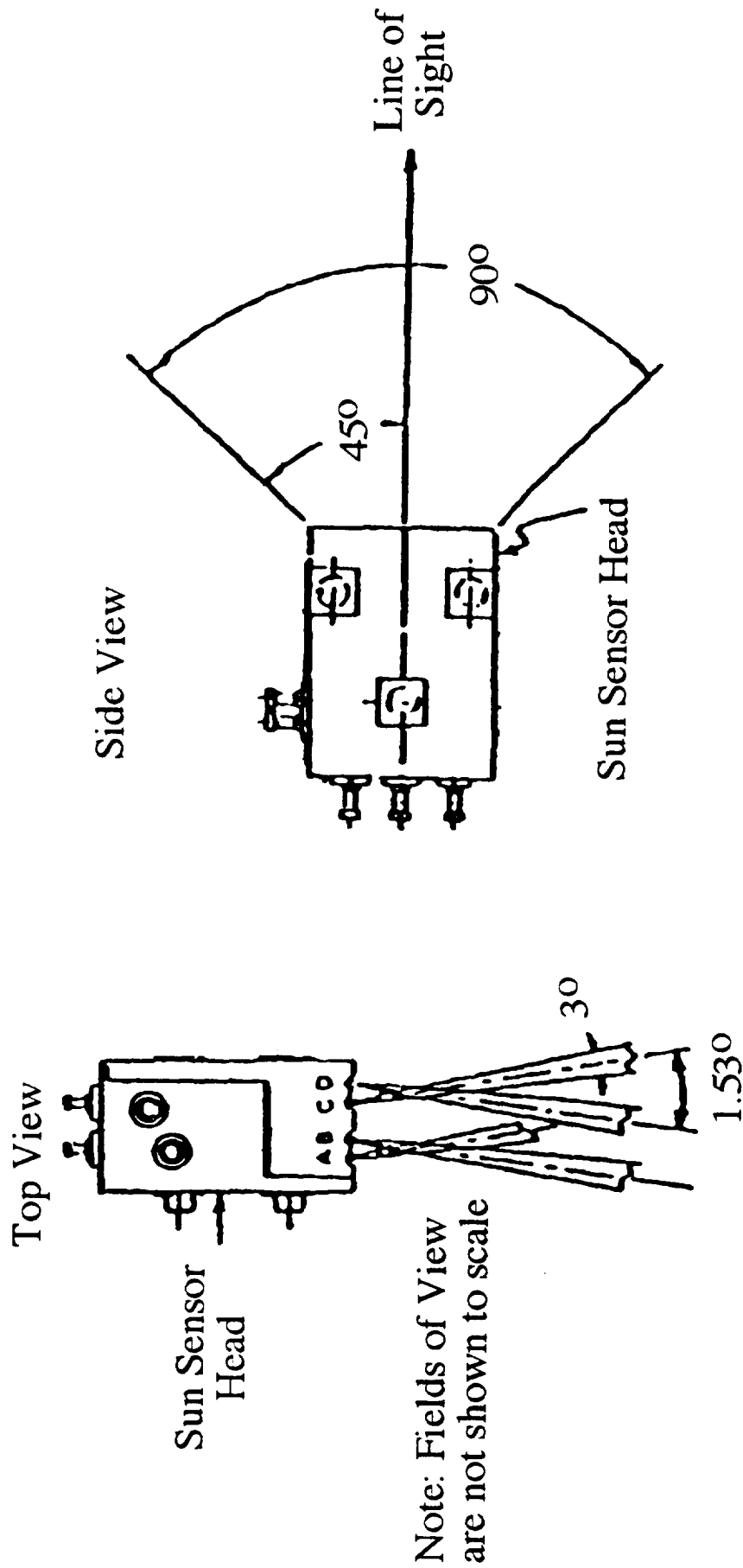
Increasing Time

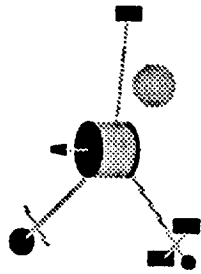


Avionics

Sun Sensor Head Field of View

LOCKHEED MARTIN

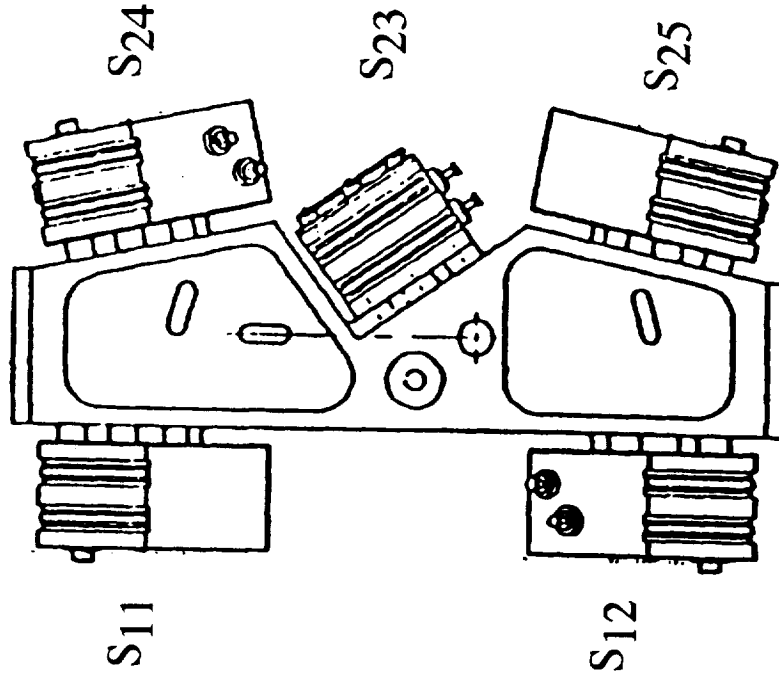




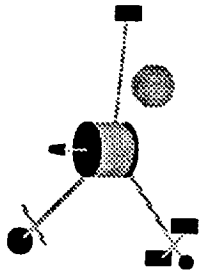
SSA Configuration

-Avionics

LOCKHEED MARTIN



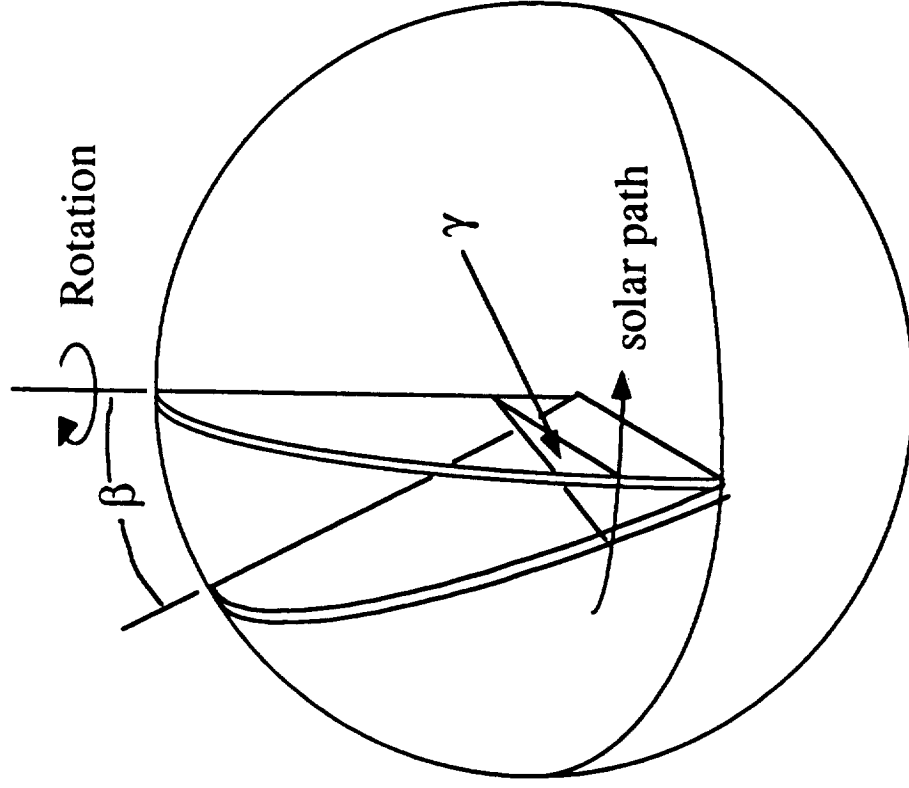
Sensor	Cant	Elevation
S ₁₁	0°	30°
S ₁₂	0°	-30°
S ₂₃	30°	0°
S ₂₄	12°	31°
S ₂₅	-12°	-31°

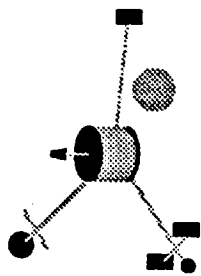


Avionics

Canted SSH Configuration

LOCKHEED MARTIN



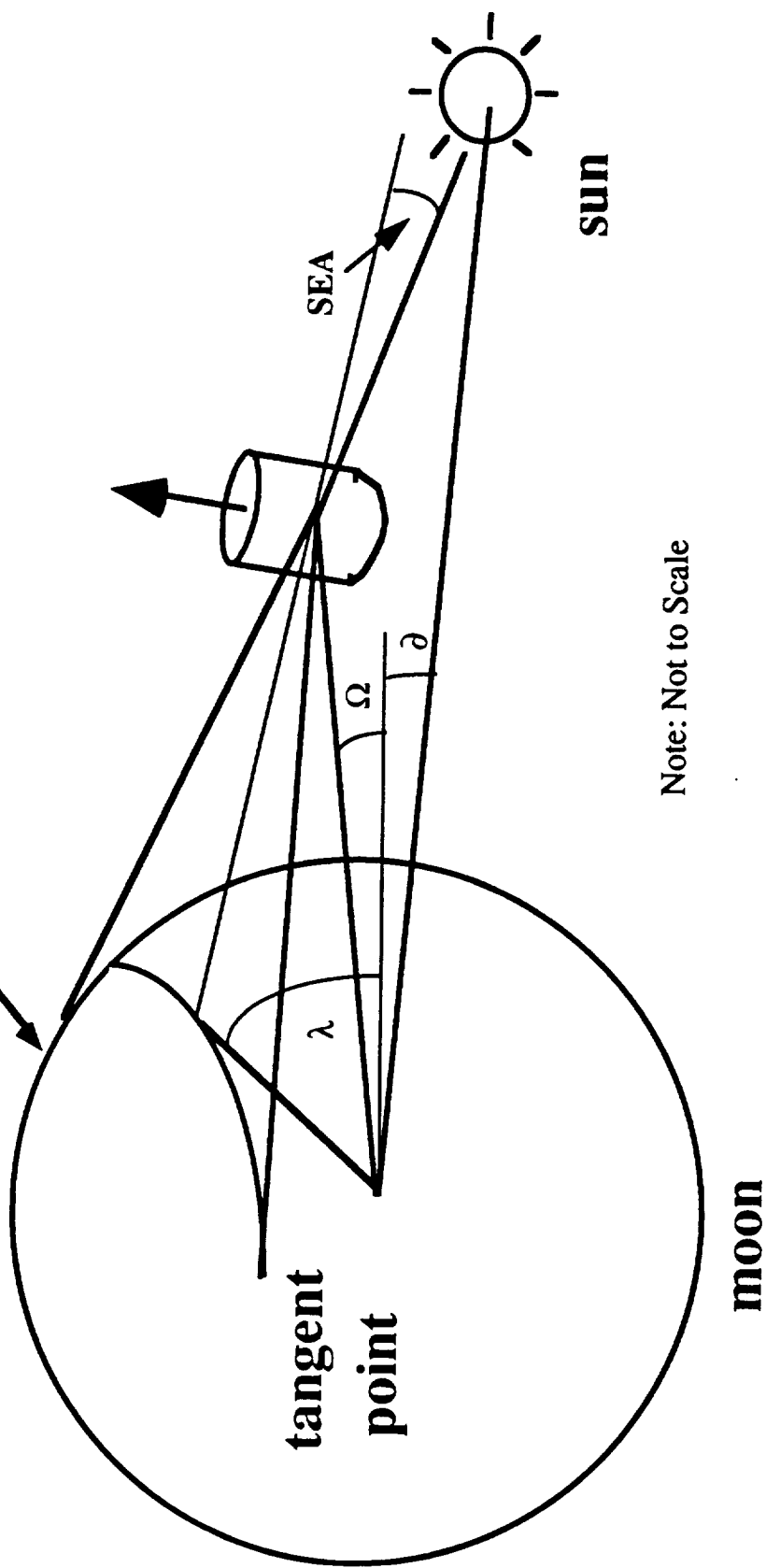


Limb Crossing Sweeps

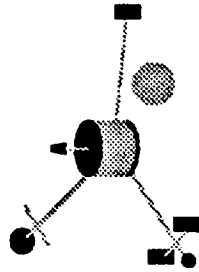
-Avionics

LOCKHEED MARTIN

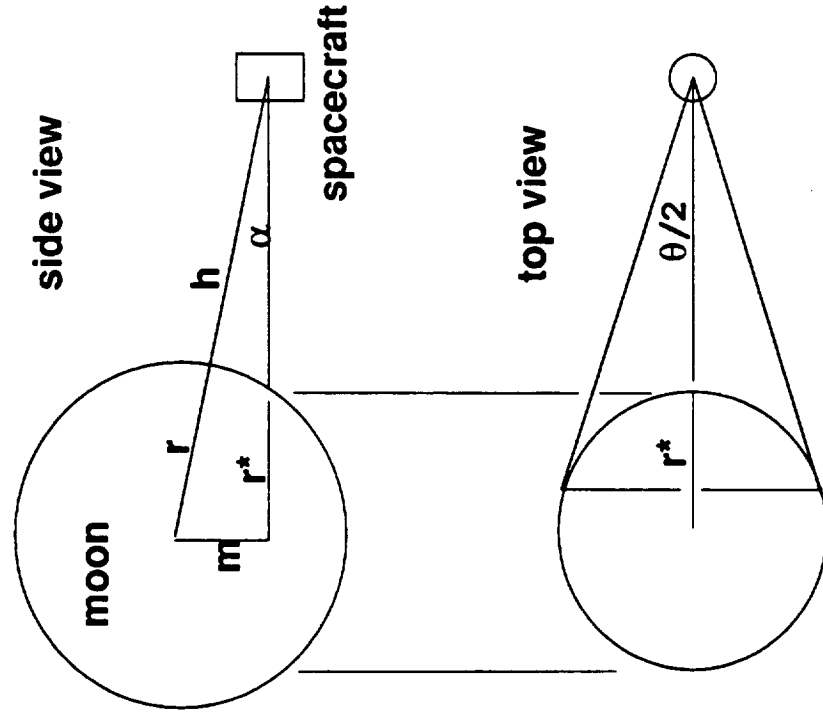
LCS track



Note: Not to Scale



Limb Crossing Sensor Detection Geometry



To determine the arc length and chord width for an arbitrary sweep:

$$m = (r + h) \sin \alpha$$

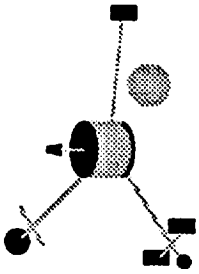
$$r^* = [r^2 - m^2]^{1/2}$$

$$\sin \theta/2 = r^* / (r + h) \cos \alpha$$

$$\text{lunar chord} = 2 r^* \cos \theta/2$$

$$\text{lunar arc} = 2 r \arcsin p / r^*$$

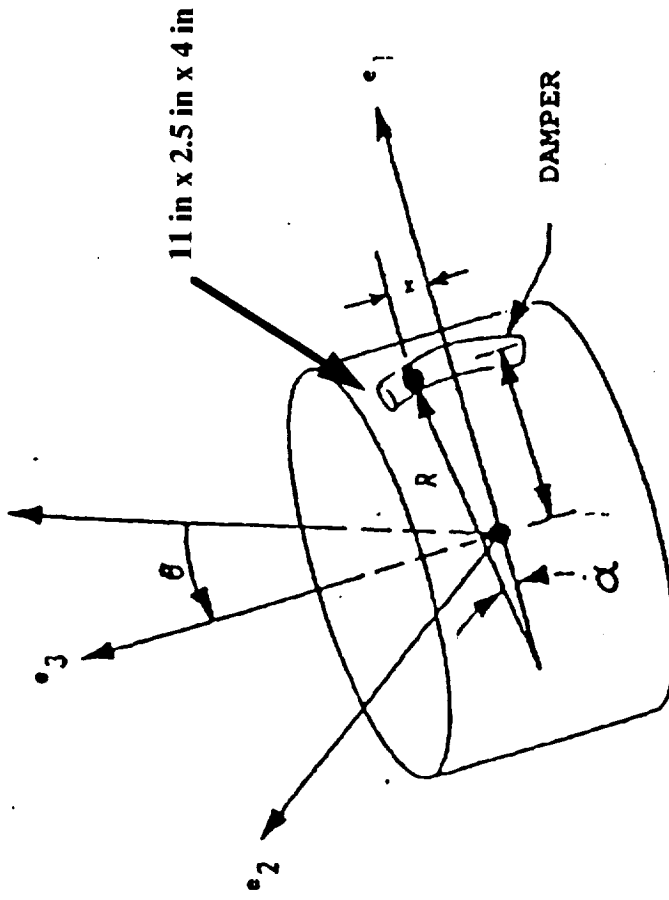
where $p = 1/2$ the chord length

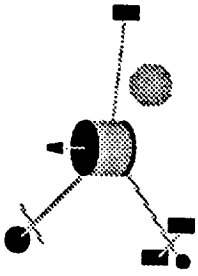


Avionics

Nutation Damper Geometry

LOCKHEED MARTIN





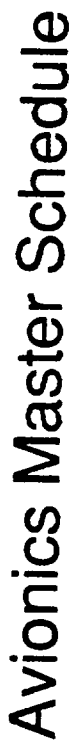
-Avionics

LOCKHEED MARTIN



Test Program

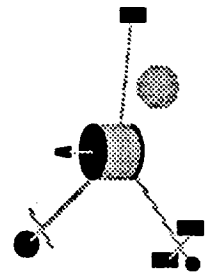
- Breadboard Testing validates interfaces
 - Engineering Models (Sun Sensor, Limb Sensor, C&DH Unit, Spectrometer Electronics, Mag/ER Electronics)
 - Software Models (Cmd/Tlm Generation and Display)
- Equipment Protocol Acceptance assures performance capability
 - Functional Testing verifies equipment parameters
 - Environmental testing verifies performance ranges and workmanship
 - Shock, Random Vibration, Thermal Vacuum
- Subsystem Level Acceptance assures system performance capability
 - Sun Sensor Assembly and Alignment
 - Communications Subsystem performance (Implementation losses)
 - Limb Sensor Installation and Alignment
- System Functional Performance testing
 - Functional testing demonstrates overall system performance
 - Environmental testing verifies performance capability
 - System operation time accumulated to assure equipment reliability



■Avionics

LOCKHEED MARTIN



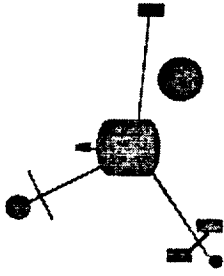


Avionics

Issues

LOCKHEED MARTIN

- Develop understanding of Flight Dynamics (Attitude Uncertainty)
 - At Booster Tip-off
 - Through TLI Firing
 - After TLI Staging
 - After Boom Deployment
 - As affected by Vector Burns (Mid course, capture, orbit maintenance)
- Develop nutation damping requirements (Attitude Control)
- Develop vector burn commanding requirements (Attitude Control)
- Confirmation of Sun and Limb Sensor Detection Strategy
 - Definition of Attitude Determination Algorithms
 - Near Earth capability to support trans-lunar injection
 - Near Moon capability to support parking orbit capture
 - Mapping orbit capability to support mission operations
- Selection of Limb Sensor wavelengths



■ ACS Analysis

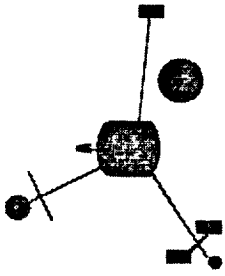
LOCKHEED MARTIN



Attitude Control System Analysis

George Schmidt

GES 8/31/95



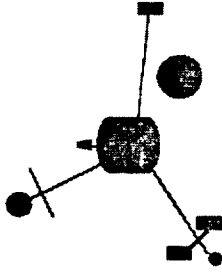
Mission Attitude "Control"

Requirements

ACS Analysis

LOCKHEED MARTIN

- Trans-lunar kick motor thrust axis orientation within 5° (TBR) of nominal
- Reorient spin axis post TLI-burn by open-loop ground-commanded thrust actuated precession
 - Maneuver resolution compatible with antenna (spin-axis) pointing and lunar capture
 - Cruise attitude within 5° (TBR) of normal to the ecliptic plane
- Provide sun and moon observation data
 - For spin-axis attitude determination on the ground
 - Near-earth capability to support TLI trajectory correction
 - In lunar vicinity to support parking orbit capture
 - In mission orbit to support attitude maintenance
 - For on-board spin phase definition
 - For spin rate determination
- Control spacecraft spin rate by open-loop ground-commanded thrusting



Areas of Investigation

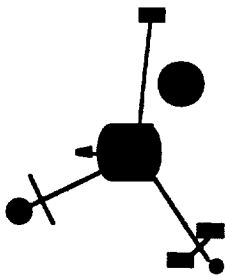
■ ACS Analysis

LOCKHEED MARTIN



- Booster separation dynamics and TLI firing
 - Spin stability / nutational divergence
 - Active nutation damping
 - TLI-burn attitude uncertainty
- Post TLI attitude uncertainty
 - Spin precession maneuver error sources and sensitivities
 - Spin rate control error sources and sensitivities
- Deployable boom issues
- Vector burn sensitivities
- Attitude sensing
 - Define approximate sensing regions

Investigations use experience gained from
Global Geospace Science (GGS) Program



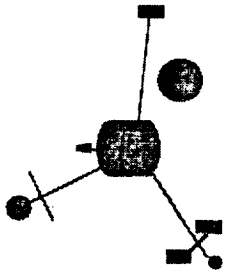
LP/GGS Comparison

■ ACS Analysis

LOCKHEED MARTIN

- GGS (Global Geospace Science) consists of two spacecraft, WIND and POLAR, built by Lockheed Martin Astro Space. WIND is currently in orbit, POLAR will be launched December 9.

GGS		Lunar Prospector
Direct inject to desired orbit	Trans lunar injection stage	
Spin stabilized - Major axis spinner at booster separation	Spin stabilized - Minor axis spinner at booster separation	
ABLE deployable booms - 12 meters WIND - 6 meters POLAR	ABLE deployable booms - 2.5 meters	
Ground-based attitude determination and control	Ground-based attitude determination and control	
Spin-synchronized, commanded time thruster pulsing	Spin-synchronized, commanded time thruster pulsing	
Attitude determination using sun and horizon crossings - Limb sensing near Earth (<9.2 Re) only - Celestial sensor used on WIND	Attitude determination using sun and horizon crossings - Limb sensing near Earth and moon	
0.2° attitude knowledge	0.5° attitude knowledge	
1.0° spin axis pointing	5.0° spin axis pointing	
Bladderless propellant tanks	Bladderless propellant tanks	



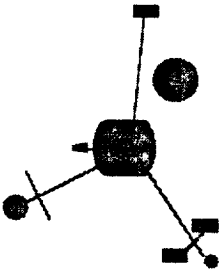
ACS Analysis

Attitude at Kick Motor Firing

LOCKHEED MARTIN

- Worst-case momentum vector pointing error at kick motor ignition is 2.7°

Error Source	Sensitivity of kick motor firing attitude	Nominal value	Contribution to total error
Launch vehicle attitude error at separation	1° per degree of attitude error	1° per axis	1.4°
Separation tipoff rates	1° per deg/sec of tipoff rate per second of delay till spin motor firing	1.0° /sec per axis tipoff rate 1.2 second delay till spin motor fire	1.7°
Spin motor firing	0.7° per deg/sec of tipoff rate	1.5° /sec per axis	1.5°
Precession caused by nutation induced by tipoff rate	0.005° per percent spin motor mismatch per inch of offset from spin motor plane to CM plane	5% mismatch of spin motors 5 inch offset from spin motor plane to CM plane	0.1°
Precession caused by mismatched spin motors			
RSS total error			2.7°



Nutation Divergence Before Kick Motor Separation

ACS Analysis

LOCKHEED MARTIN

- Lunar Prospector is a minor-axis spinner prior to separation from STAR37
- Spin about minor axis is unstable - nutation will grow due to internal energy dissipation, eventually resulting in a flat spin
- Lunar Prospector has two significant energy dissipaters:
 - Propellant slosh
 - The ball-in-tube nutation damper (which works as a de-damper when spin is about the minor axis)
- Estimated divergent time constants for propellant slosh:
 - 90 seconds for initial tank design (spherical tank with bladder)
 - 1600 seconds for an alternative tank design (GGS tanks: hollow sphere with sump and no bladder)
- The ball-in-tube nutation damper will reduce the time constant further
 - magnitude of the additional reduction has not been analyzed
- Delay between STAR37 burnout and separation must be at least 240 seconds (TBR) to prevent recontact due to chuffing

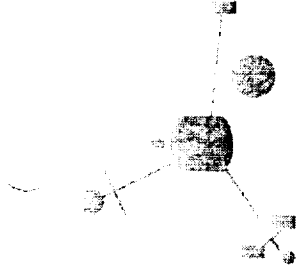
Recommendations to Reduce

Nutation Divergence

■ ACS Analysis

LOCKHEED MARTIN

- Switch to a no-bladder tank design (GGS) to minimize rate of divergence
 - 22.0 inch hollow spherical titanium hydrazine tank
 - Operating pressure range 0-400 psia
 - Bubble trap sump at outlet
 - Mass: 5.67 kg
 - Vendor: PSI
- Implement an active nutation control system to be used between burnout of kick motor and separation
 - 240-second minimum delay required for kick motor chuffing
 - Significant uncertainty in divergent time constant => nutation likely to be too large to tolerate
 - Active nutation control not required anytime else in mission
 - Insufficient time between spin-up and kick motor ignition for significant nutation growth
 - Jet damping controls nutation during kick motor burn
 - After separation Lunar Prospector is a major-axis spinner; active nutation control is unnecessary



Active Nutation Damping System

■ ACS Analysis

LOCKHEED MARTIN

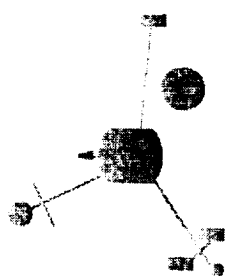


- Active Nutation Damping System

- Recommended following the STAR37 firing through separation
- Flight-proven active nutation damping system (Astro Space ACTS, Telstar 401, and S3000 communication satellites) applicable to Lunar Prospector

- Description

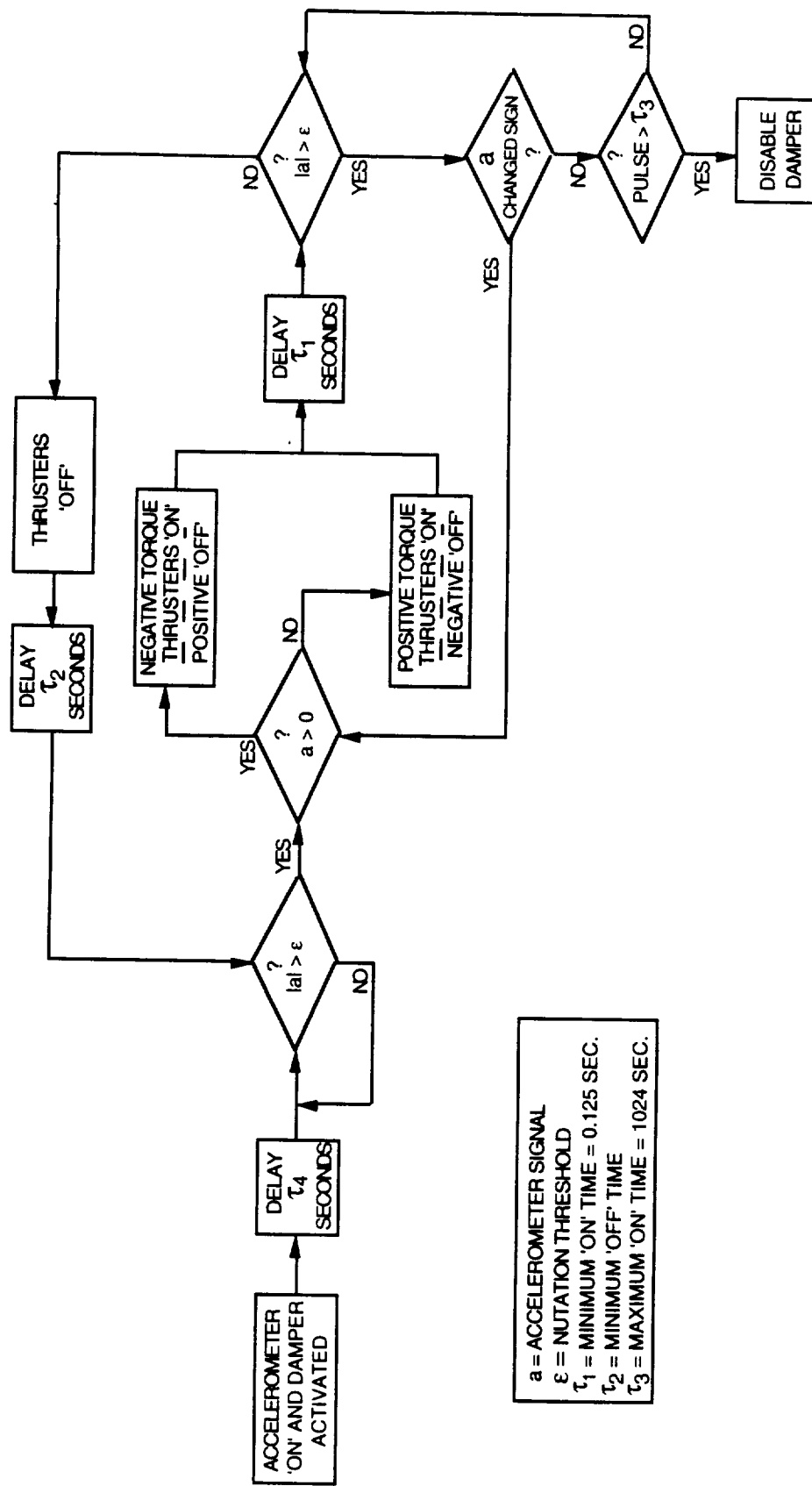
- Active nutation damping provided by firing axial thrusters based on accelerometer output
 - Axial thrusters provide torque about the x-axis
 - Remove nutation when the x-axis body rate is maximum as indicated by the accelerometer
- Filter accelerometer output with a unity-gain, zero-phase band-pass filter centered about nutation frequency to remove DC biases and noise
 - Relatively insensitive to nutation frequency (not highly tuned)
- Fire thrusters while the accelerometer output is greater than a threshold
 - Pulsewidth grows with nutation amplitude up to maximum (one half nutation period)
 - Threshold sets the nutation level to be maintained



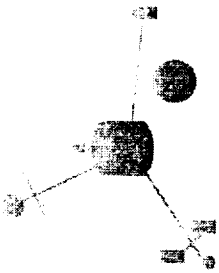
Active Dumper Logic

ACS Analysis

LOCKHEED MARTIN



a = ACCELEROMETER SIGNAL
 ε = NUTATION THRESHOLD
 τ₁ = MINIMUM 'ON' TIME = 0.125 SEC.
 τ₂ = MINIMUM 'OFF' TIME
 τ₃ = MAXIMUM 'ON' TIME = 1024 SEC.



Accelerometer Characteristics

■ ACS Analysis

LOCKHEED MARTIN

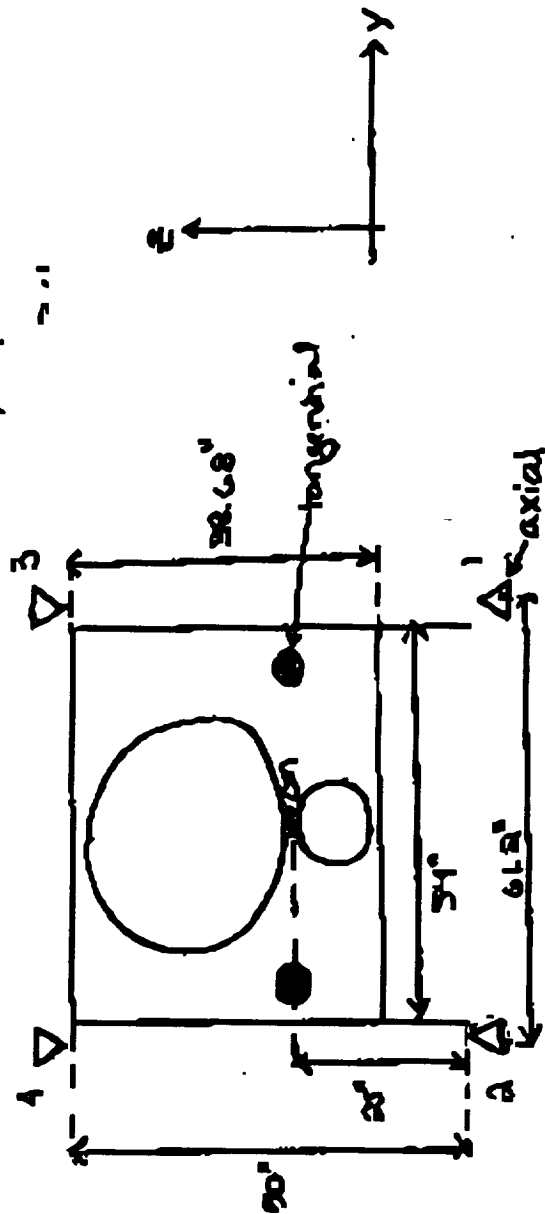
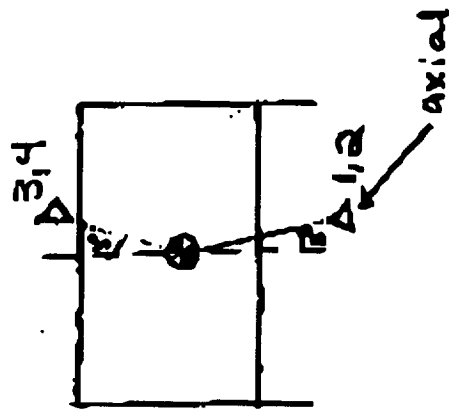
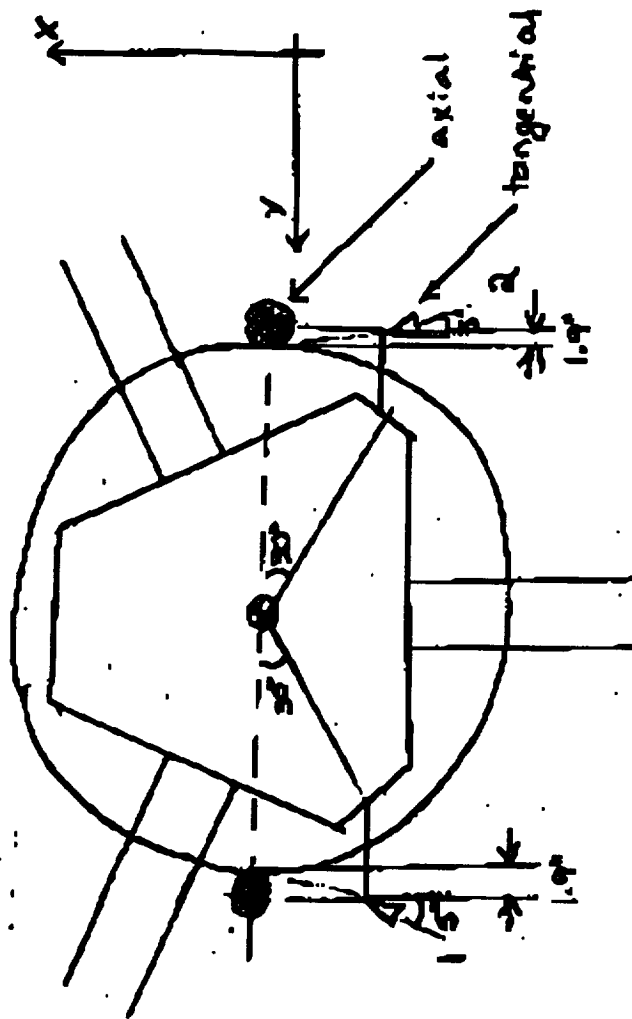


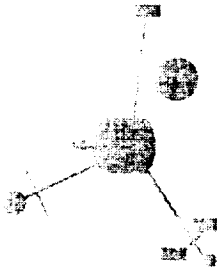
- Systron Donner (Astro Space Part No. 2308612) accelerometer is a candidate nutation sensor
 - Weight: 190 grams
 - Power: 0.24 Watt
 - Size: 5.84 x 6.4 x 7.6 cm
 - Range: 0 to $\pm 3g$, full scale (TBR)
 - Scale Factor: $2.5 \pm 1\%$ Vdc/g at $25^\circ C$
 - Null Offset: $\pm 0.0015 g$ at $25^\circ C$
 - Resolution: $20 \times 10^{-6} g$
- Design Requirements:
 - Location: outboard along the +x axis at the elevation (z-coordinate) of the spacecraft center of mass (with the STAR37 motor case still attached)
 - y and z axis placement tolerance needs to be established
 - Orientation: parallel to the +z axis within 0.1°

Thruster Layout Sketch

ACS Analysis

LOCKHEED MARTIN





Spin Precession Maneuvers and

Error Sources

■ ACS Analysis

LOCKHEED MARTIN



- Precession (reorientation) maneuvers performed by executing the following sequence a ground-specified number of times
 - 1. Watch for CEP for reference sun sensor
 - 2. Delay for a ground-specified time
 - 3. Fire A1/A3 for a ground-specified time
 - 4. Delay till 1/2 spin period after start of step 3
 - 5. Fire A2/A4 for a ground-specified time
- Maneuver errors sources considered:
 - mismatched thrust levels
 - misalignment of thruster vector (affects moment arms and spin rate change during maneuver)
 - truncation of maneuvers to an integer number of spin periods
- Two maneuvers examined
 - 90 degree precession to cruise attitude (stowed configuration)
 - 180 degree precession at six months (deployed configuration)

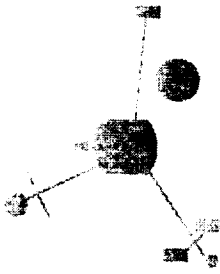
- Worst-case attitude error at end of maneuver using current time-based commanding:

	5% thrust level uncertainty		3% thrust level uncertainty	
	0.1° thrust vector misalignment	1° thrust vector misalignment	0.1° thrust vector misalignment	1° thrust vector misalignment
90° precession (stowed)	3°	15°	2°	15°
180° precession (deployed)	10°	67°	9°	67°

Note: the 0.1° and 1° misalignments are intended only to show sensitivity to misalignments. Actual misalignment requirement should be based on S/C pointing requirements. GGS value is 0.23°.

- Recommendation: change to angle-based commanding (specify fractional spin period delay instead of absolute time delay)
 - Minimizes impact of spin rate change during maneuvers
 - Requires hard-wired on-board calculation of current spin rate using CEP's, and conversion of delay angles to time
- Worst-case attitude error using angle-based commanding:

	5% thrust level uncertainty		3% thrust level uncertainty	
	0.1° thrust vector misalignment	1° thrust vector misalignment	0.1° thrust vector misalignment	1° thrust vector misalignment
90° precession (stowed)	3°	3°	2°	2°
180° precession (deployed)	5°	7°	3°	5°



Attitude Error at End of Precession to Cruise Attitude

ACS Analysis

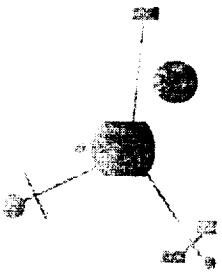
LOCKHEED MARTIN

Two cases examined

- 1) Use baseline maneuver sequence and commanding
- 2) Make changes recommended elsewhere in this package to active nutation damping and SPM maneuver commanding

Error Source	Case 1 Contribution to total error	Case 2 Contribution to total error
Attitude error at kick motor ignition	2.7°	2.7°
Precession due to kick motor firing (assuming 0.1 inch offset between thrust centerline and spacecraft CM)	4.2°	4.2°
Active nutation damping thruster pulses	0.0°	0.5°
Precession induced by nutation at separation from kick motor (assuming 2.5° nutation at kick motor burnout, active nutation damping controls nutation to 1.0°) [bladdered tanks / GGS tanks]	24.0°/1.9°	0.7°
Transverse torques at separation from kick motor	0.3°	0.3°
Precession induced by spin down to 20 rpm	0.0°	0.0°
Attitude error associated with 90° precession to cruise attitude (thrusters misaligned 0.25°)	5.0°	3.0°
RSS Total	25.0/7.3°	5.9°

- MGA requires $\pm 5.0^\circ$ pointing accuracy. Need additional work to reduce pointing error, or need to increase range of MGA.



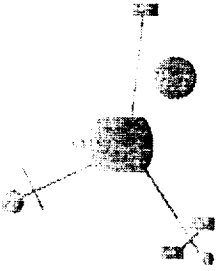
Mass Properties Issues

■ ACS Analysis

LOCKHEED MARTIN



- An inertia ratio requirement is needed for the spacecraft after separation from the kick motor to ensure rotational stability
 - Driven by moments of inertia
 - Recommend inertia ratio be at least 1.04 (based on experience with GGS, Dynamics Explorer, and various communication satellites)
- A cone angle requirement is needed for the spacecraft after separation from the launch vehicle to ensure MGA coverage
 - Driven by products of inertia (POI)
 - Based on $\pm 5^\circ$ range of MGA, recommend cone angle be less than 0.5° (order of magnitude less than MGA range)
 - To satisfy this requirement using 24-August-95 mass props, POI restrictions are
 - Attached to kick motor: $POI < 1.96 \text{ kg-m}^2$
 - Stowed: $POI < 0.08 \text{ kg-m}^2$
 - Deployed: $POI < 0.92 \text{ kg-m}^2$



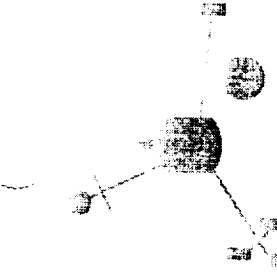
Deployable Boom Issues

■ ACS Analysis

LOCKHEED MARTIN



- Boom flex frequencies
 - Pulsed thruster maneuvers execute at spin frequency
 - Could pump boom flex modes if flex frequency is near spin frequency
 - Need a requirement that boom flex frequencies be at least 50% greater than spin frequency to minimize risk of coupling
 - Available boom frequency data indicates that satisfying this requirement is not an issue (boom frequency >60 rpm, spin rate is 12 rpm)
- Boom mass properties modeling
 - Deployed booms are dominant component of spacecraft moments of inertia
 - Mass properties of spacecraft with deployed booms can only be determined analytically, not by test
 - Careful accounting of boom mass properties is required
 - Moments of inertia to ensure inertia ratio requirement for deployed spacecraft is satisfied
 - Products of inertia to ensure cone angle requirement for deployed spacecraft is satisfied
 - Similar accounting performed successfully on GGS



Vector Burn Sensitivity Issues

– ACS Analysis

LOCKHEED MARTIN



- Thrusting deviations during vector burn produce undesirable effects
 - Spin rate change
 - Precession
 - Misdirected Delta-V
- Thrusting deviations result from:
 - Center-of-mass shifts from design location
 - Thrust mismatch
 - Thruster misalignments from design orientation
- Sensitivity analysis performed to quantify effect of each error source
 - Examined Tangential and Axial ΔV s separately
 - Tangential ΔV produced by pulsing both tangential thrusters once a spin period
 - Axial ΔV produced by continuously firing base-panel axial thrusters
 - Examined each error source independently

Vector Burn Sensitivities

■ ACS Analysis

LOCKHEED MARTIN

- For an axial ΔV , the worst-case sensitivities are:
 - 0.2 rpm spin rate change for each meter per second of ΔV for each degree of thruster misalignment in the xz plane
 - 0.01° precession for each degree of thruster misalignment
 - 0.008° precession for each % of thruster mismatch
- For each meter per second of tangential ΔV (with a 60° pulse width), the worst-case sensitivities are:
 - 0.09 rpm spin rate change for each % of thruster mismatch
 - 1.8° precession for each inch of center-of-mass offset in the $\pm z$ direction
 - 0.5° precession for each degree of thruster elevation misalignment
- RECOMMENDATIONS:
 - Command tangential thruster pulsing delays by fractional spin period rather than delay time to reduce heading errors due to spin rate change
 - Pulse one axial thruster during a tangential ΔV to minimize precession
 - Requires capability to independently command delay angles and pulse widths for each thruster
 - Remove 5° cant on the tangential thrusters

Attitude Determination

■ ACS Analysis

LOCKHEED MARTIN



- Spin axis attitude determined from earth/moon limb crossing data and sun angle measurement
 - Ground-based computation based on cone intersection with dihedral angle to remove ambiguity
 - Sun angle determined by time interval between sun sensor slit crossings
 - Limb sensor minimum measurable chord ($\leq 8^\circ$) limits regions where attitude can be measured
 - Near-Earth region - within 85,000 km of the Earth (best-case)
 - Near-lunar region - within 23,000 km of the moon (best-case)
- Spin phase measured relative to sun sensor crossing (command eye) pulse
- Spin rate determined by time interval between command eye pulses
- The attitude determination approach appears feasible, but issues remain to be addressed

Attitude Sensing Issues

■ ACS Analysis

LOCKHEED MARTIN



- Limb sensing of the moon will require sensor modification/development from baseline sensor
 - Modify spectral bandpass for moon sensing
 - Baseline sensor is 14 - 16 micron
 - Would possibly need 30 -100 micron
 - Impact on earth measurement accuracy needs to be assessed
 - Increase field-of-view to improve signal-to-noise
 - Accommodate radiance dynamic range ($\approx 60:1$) for operation across lunar terminator
 - Delivery in time to meet program schedule will be difficult
- Sensor geometry and measurement region must be defined and validated for lunar capture sequence

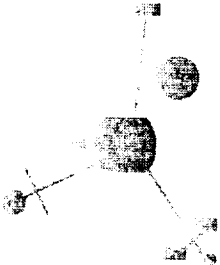
Summary of Subsystem

Recommendations

■ ACS Analysis

LOCKHEED MARTIN

- Modify spacecraft components:
 - Remove bladders from propellant tanks to reduce rate of nutation divergence
 - Add an accelerometer and associated electronics to provide active nutation control between kick motor burnout and separation
- Modify pulsed thrusting logic:
 - Allow commanding by delay angles instead of by delay times
 - Allow independent commanding of delays and pulse widths for each thruster to permit axial thrusters to compensate precession during tangential delta-V maneuvers
- Define requirements for inertia ratio and cone angle
 - Inertia ratio ≥ 1.04 after separation from kick motor
 - Cone angle $\leq 0.5^\circ$ (TBR) throughout life
- Require boom flex frequencies to be greater than 1.5 times spin frequency
- Require CM, tangential thrusters, and propellant tanks to be in the same plane to minimize precession and propellant migration between tanks



Areas for Further Study

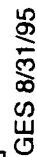
■ ACS Analysis

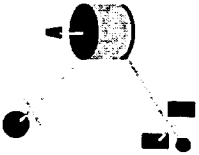
- Attitude determination
 - Limb crossing sensor requirements
 - Sensor spectral pass band
 - Field-of-view
 - Define ground processing algorithms
- Firm-up accelerometer requirements
- Detailed dynamics analyses
- Pointing analyses (budgets)
 - Mid-course maneuvers
 - Lunar capture maneuvers
 - Mission operation
- Review lunar capture mission sequence
 - Attitude determination capability
 - Spacecraft reorientation requirements
 - Thruster pulsing durations and ΔV requirements

There are no apparent technical showstoppers from an Attitude Control perspective.

- *ACS Analysis:*

LOCKHEED MARTIN





■ -Software

LOCKHEED MARTIN

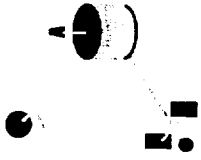


LUNAR PROSPECTOR SOFTWARE

BILL JACOBSEN

Page 1

BJ 9/6/95

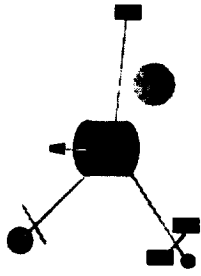


Software Key Requirements

■ -Software

LOCKHEED MARTIN

- Provide commands via transmission to the command and data handling subsystems on the S/C
- Provide capability to receive S/C telemetry
- Determine S/C attitude and spin rate from sun sensor and earth/moon limb crossing sensor data
- Determine backup S/C attitude from solar array power output and antenna radiation pattern data
- Determine hardware health status from hardware monitored data
- Determine S/C configuration using hardware monitored data



Software Key Requirements (cont.)

LOCKHEED MARTIN

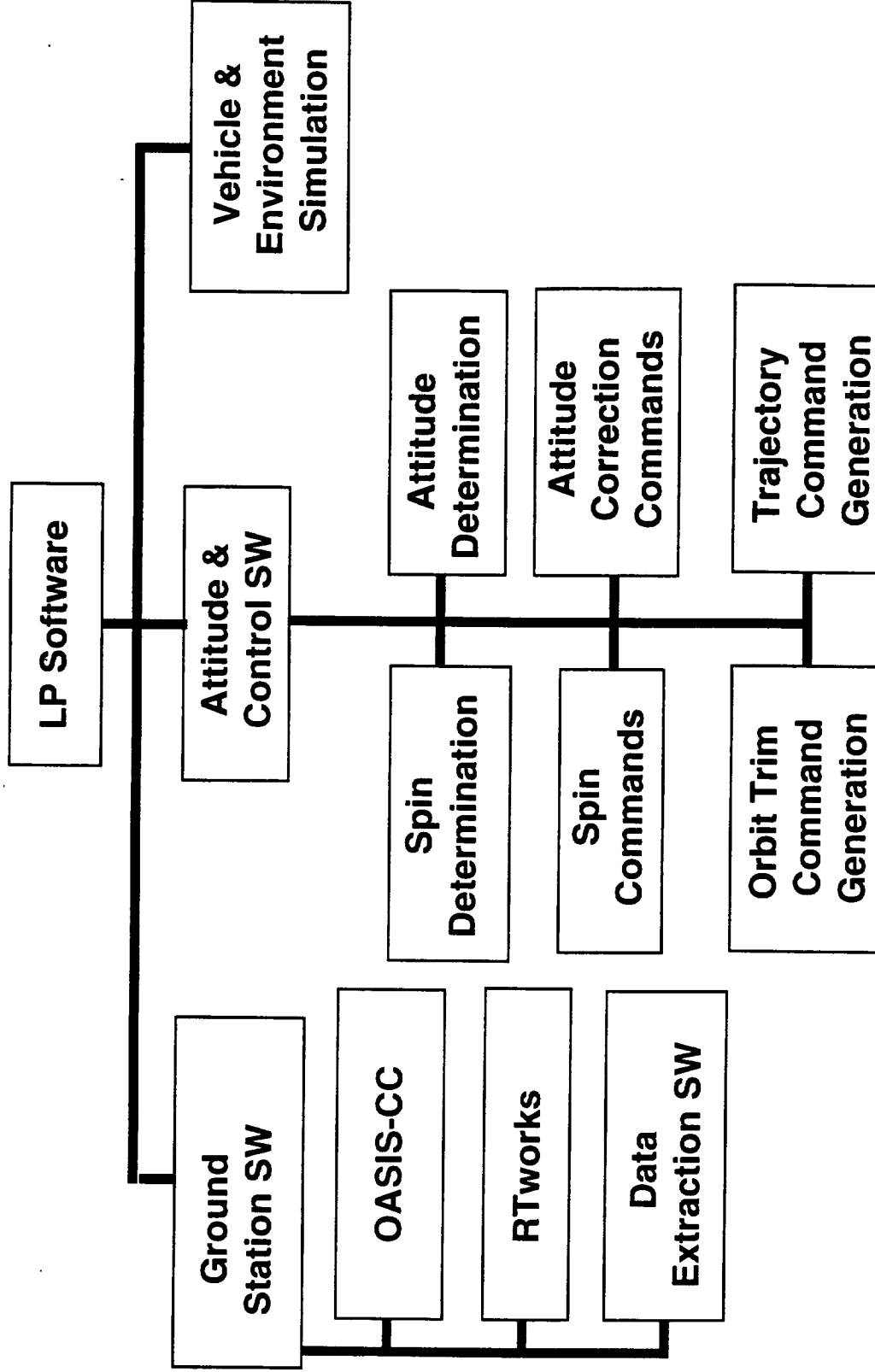
Software

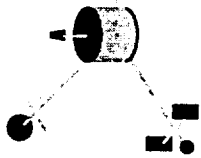
- Generate predicted S/C orientation with the latest data when S/C is occulted
- All software shall be physically located in the Ground Station (i.e. there is no flight software in the vehicle)

Block Diagram

■ - Software

LOCKHEED MARTIN





Software

Description

LOCKHEED MARTIN

CSCI Name	Function
Attitude & Control SW	
• Attitude Determination	Determine S/C attitude from sun sensor & LCS sensor data, and backup from SA power output & antenna radiation pattern data
• Spin Rate Determination	Determine S/C attitude & spin rate from sun sensor & LCS sensor data
• Attitude Correction Commands	Calculate and format attitude correction commands to S/C
• Spin Rate Commands	Calculate and format spin rate correction commands to S/C
• Trajectory Command Generation	Calculate and format trajectory commands to S/C
• Orbit Trim Command Generation	Calculate and format orbit trim commands to S/C

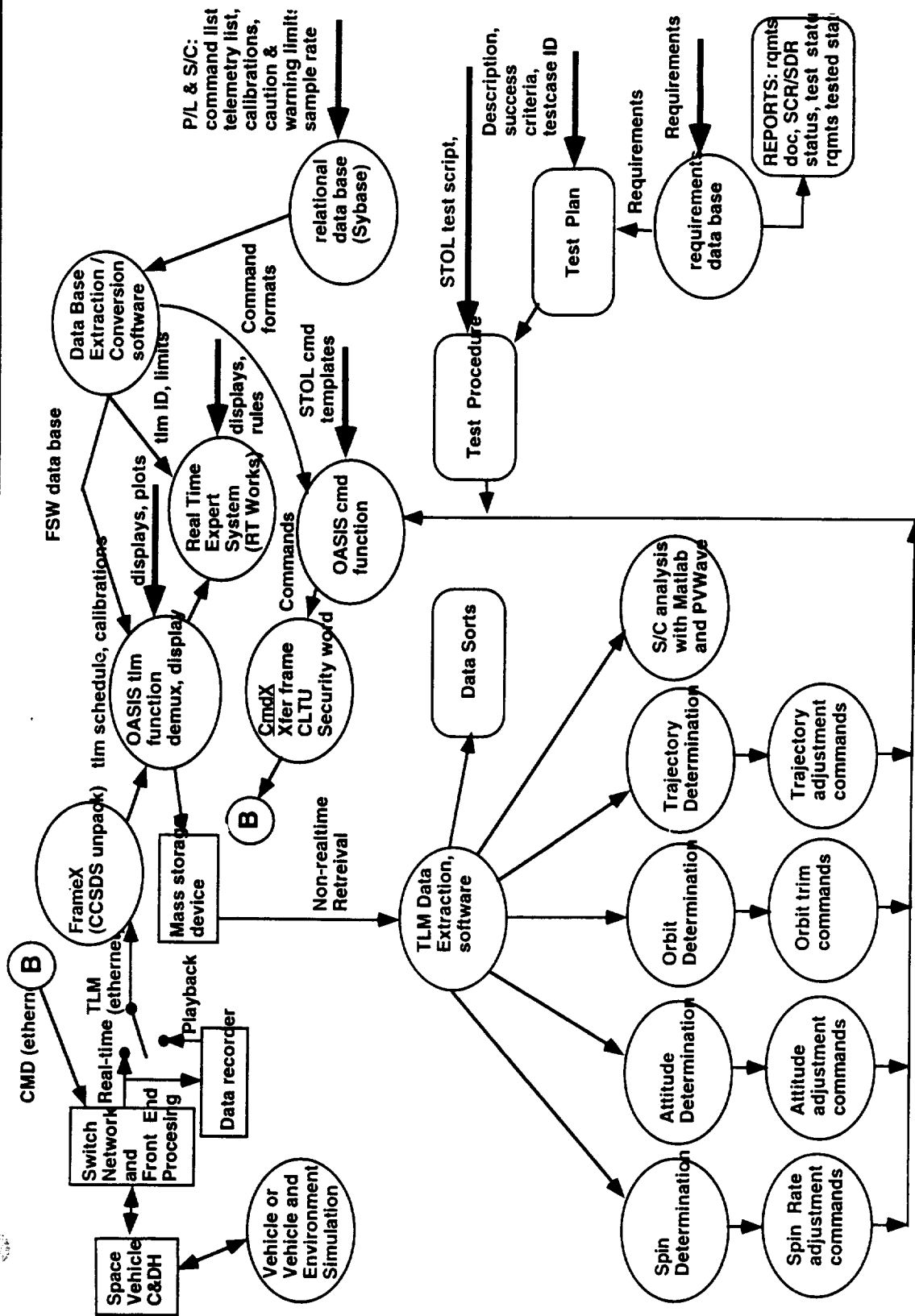
Description

■ -Software

LOCKHEED MARTIN

CSCI Name	Function
Ground Station SW	
• OASIS-CC	Test & Operations Support. Telemetry display in plot or text form, Error logging, Command line execution, Command procedure execution, CSTOL interpreter
• RTworks	Expert system. Real-time telemetry/status monitoring & rule base inferencing, Intuitive displays of telemetry data, automated configuration monitoring, automated caution & warning
• Data Extraction SW	Post test data extraction for analysis
• SYBASE RDBMS	Repository for command, telemetry definition
Vehicle & Environment Simulation	Test ground station SW, Mission planning, rehearsals

Software



CSTOL Command Procedure

■ -Software

LOCKHEED MARTIN

```

;-----
; Name:      grav_hold.prc
; Purpose   This procedure sets the observer to gravity hold and then
;           sets the limits and gains for the indicated mode.
;-----
proc grav_hold
begin
  write "begin grav_hold.prc"

  change observer config 8
  with obs_config1 4, 8
  obs_config2 4, 8
  obs_config3 4 and 8
  mode 1

  wait

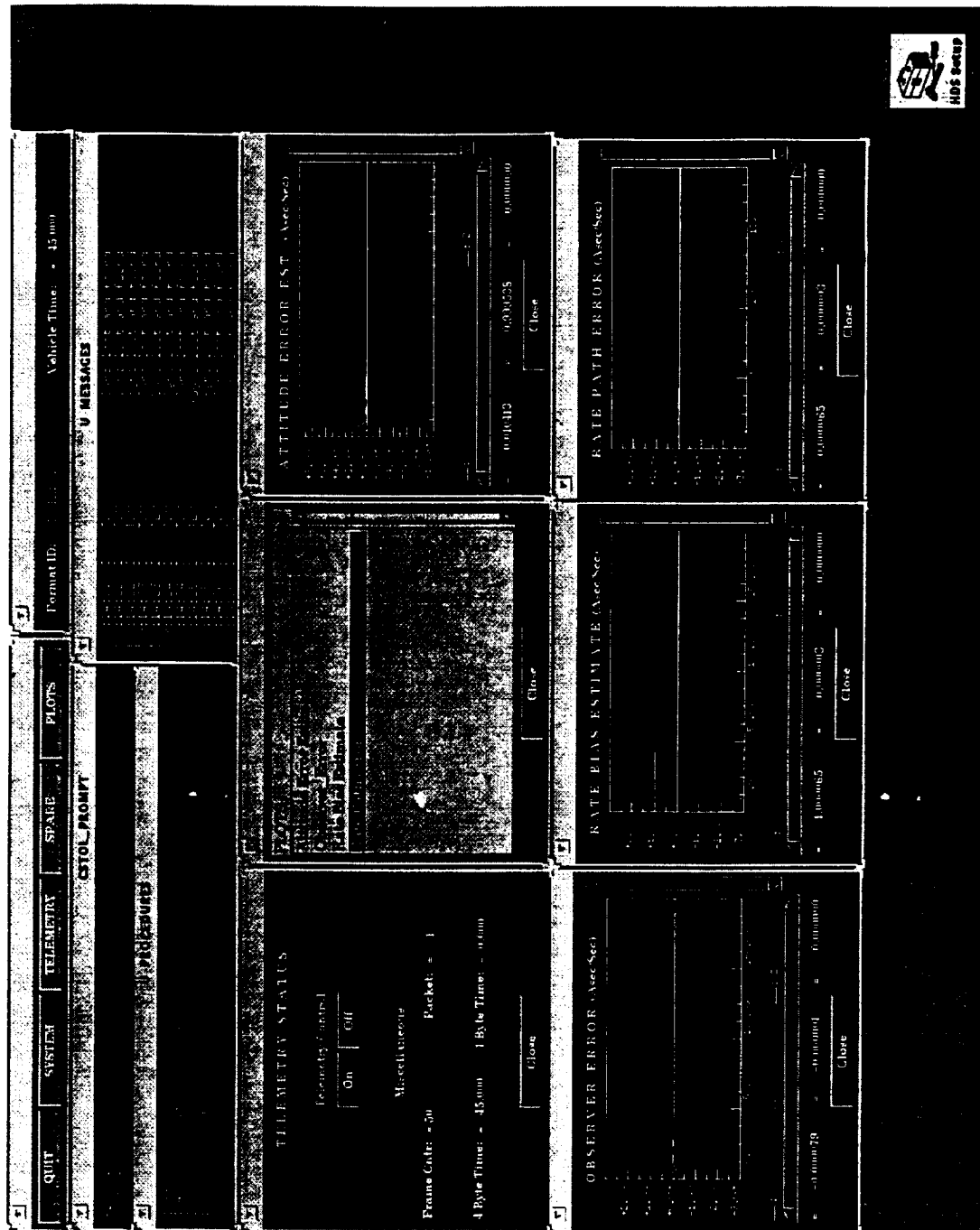
  set observer gains 8
  with temp_mode 1, 8
  tempkop1 0.62831853, 8
  tempkop2 0.62831853, 8
  tempkop3 0.62831853, 8
  tempkoi1 0.39478418, 8
  tempkoi2 0.39478418, 8
  tempkoi3 0.39478418, 8
  templim11 20.0, 8
  templim12 20.0, 8
  templim13 20.0, 8
  templim21 20.0, 8
  templim22 20.0, 8
  templim23 20.0, 8
  templim31 2000.0, 8
  templim32 2000.0, 8
  templim33 2000.0, 8
  templim01 20.0, 8
  templim02 20.0, 8
  templim03 20.0, 8
  tempkcoup 1.0

  write "end grav_hold.prc"
end proc
```

OASIS Command & Telemetry Display Windows

■ Software

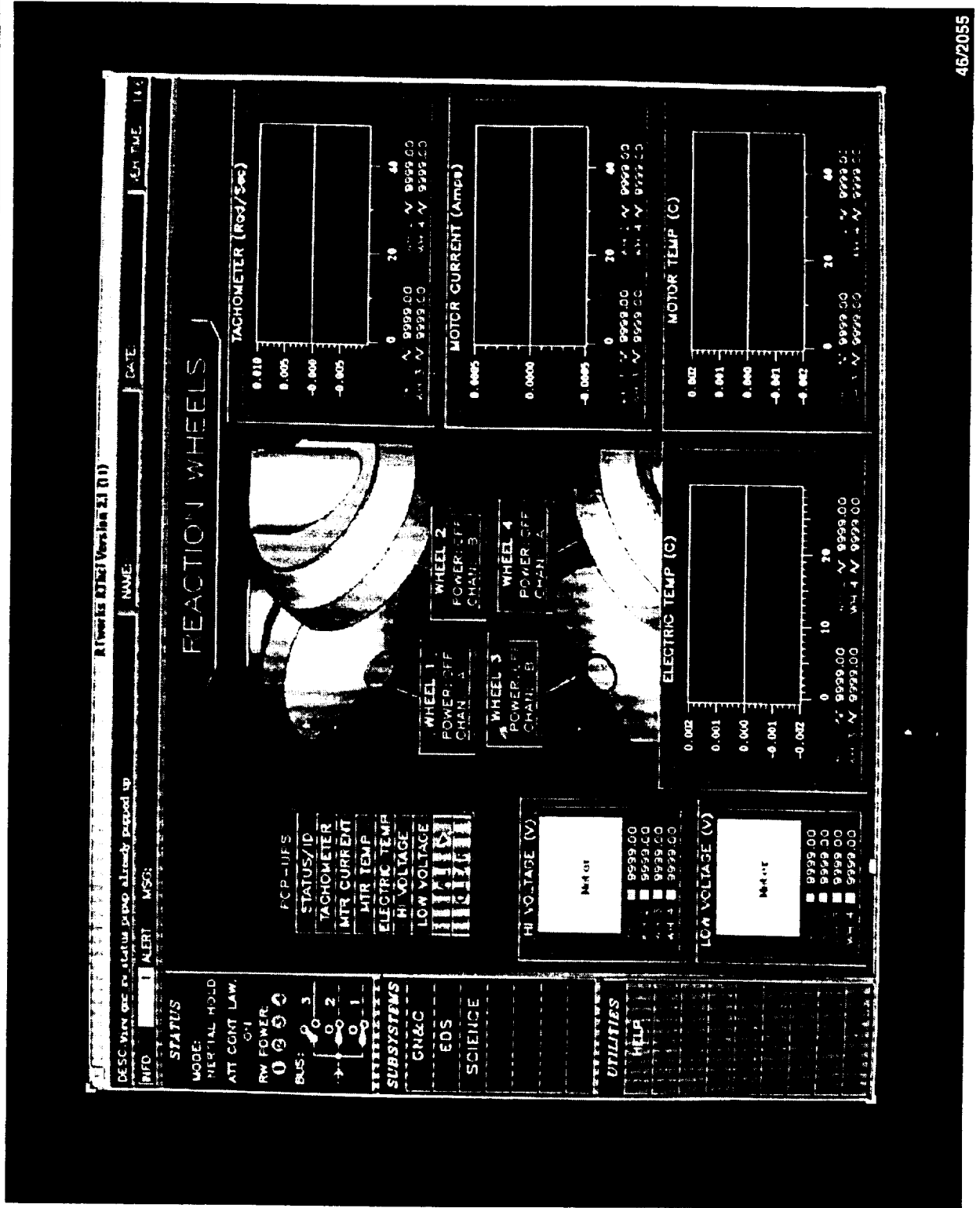
LOCKHEED MARTIN



RTworks Displays Feature CAD Imported Animated Drawings

■ -Software-

LOCKHEED MARTIN



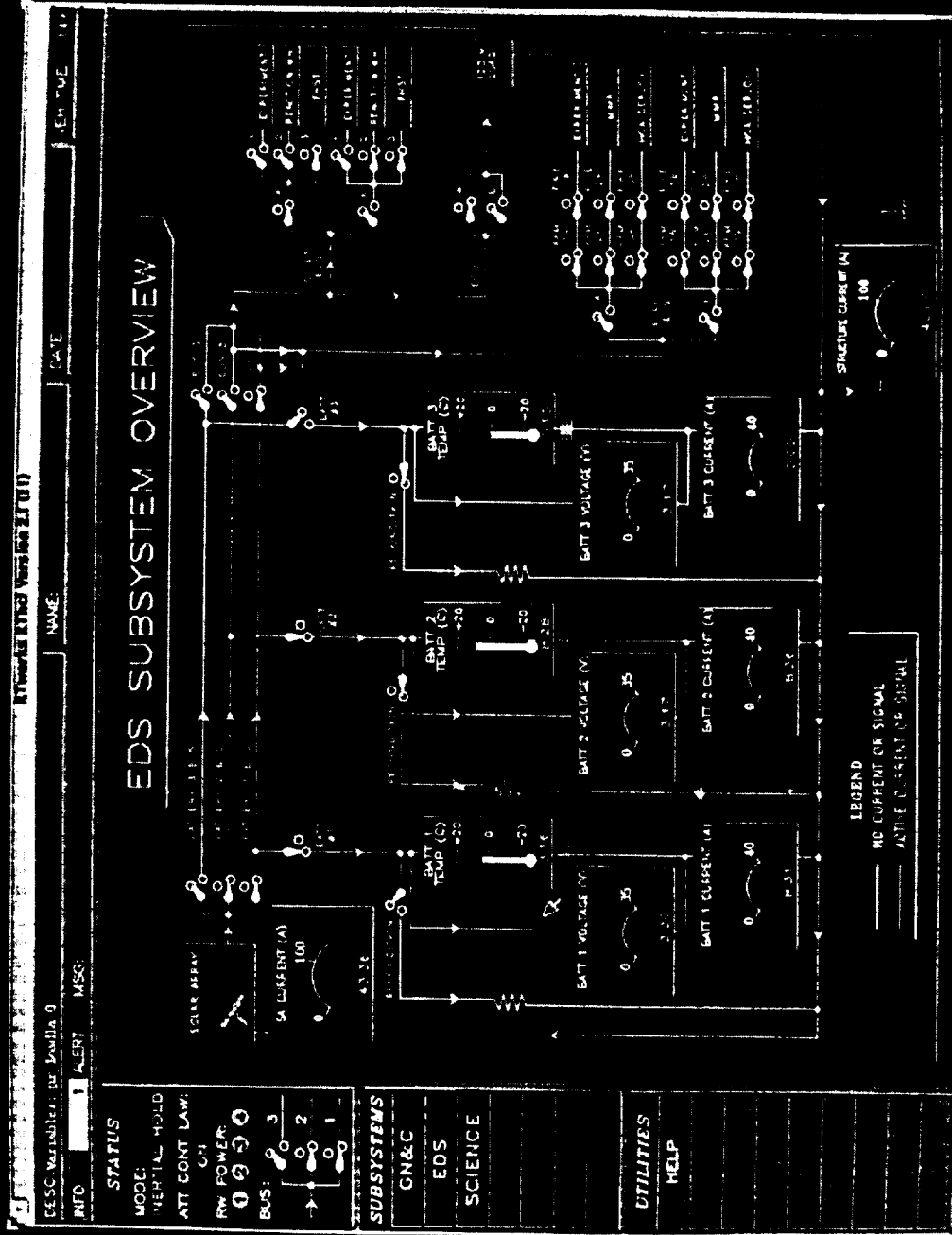
LOCKHEED MARTIN

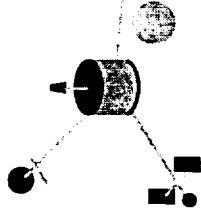


Rtworks Supports Animated Subsystem Displays

Software

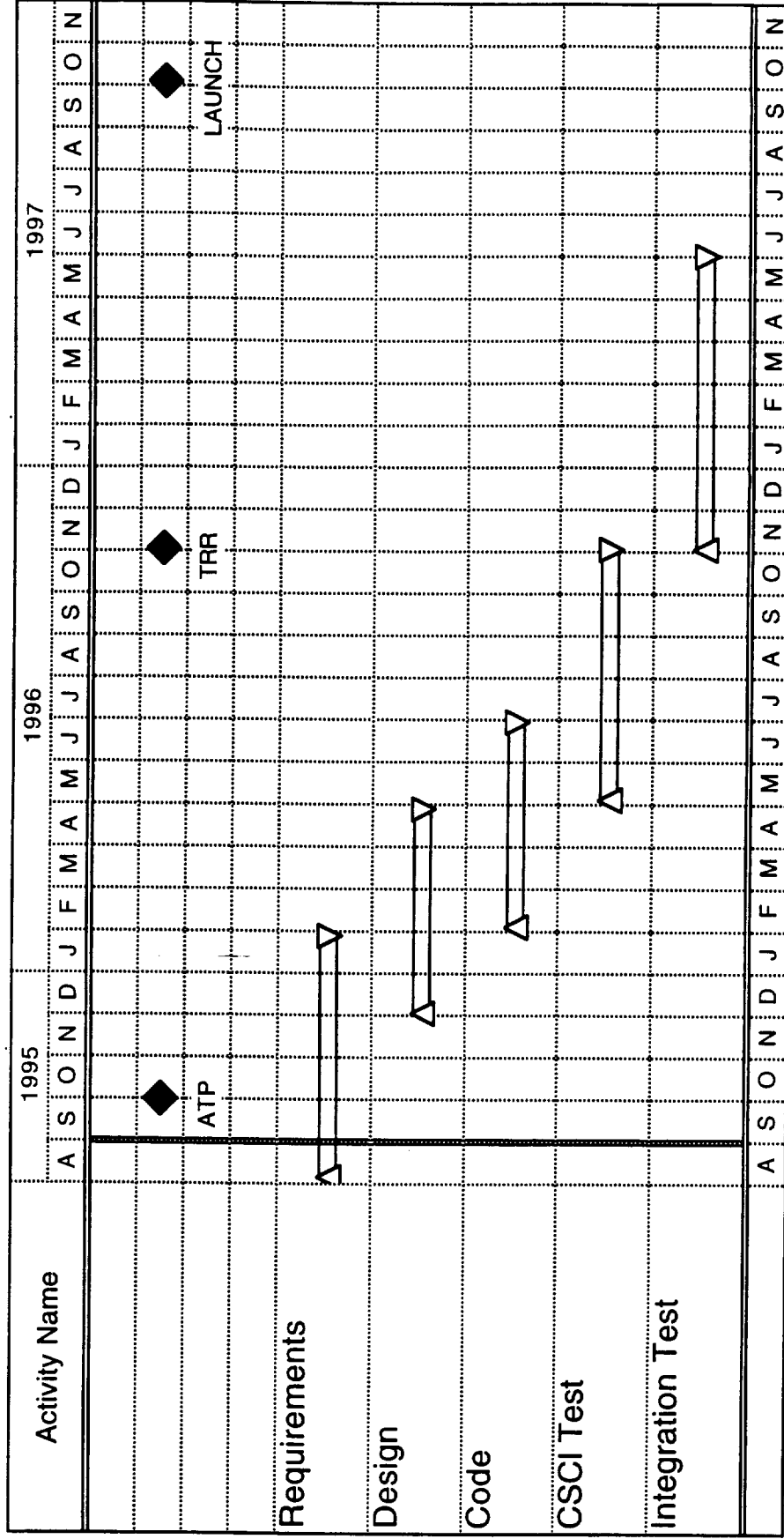
LOCKHEED MARTIN





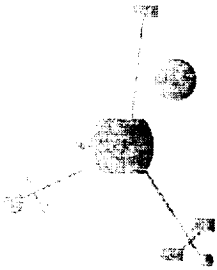
Schedule

Software



10.0 SYSTEM ASSEMBLY, INTEGRATION AND TEST

K. FOSTER



Lunar Prospector

— *Integration and Test* —

LOCKHEED MARTIN



Assembly, Integration, and Test

Kim A. Foster

LP Assembly, Integration, & Test Components

— *Integration and Test* —

LOCKHEED MARTIN



- **AI&T plan, verification methods**
- **Test procedures**
- **MO procedures & checkout**
- **Ground test software**
- **Database development**
- **Database transition to MO**
- **GSE - electrical, mechanical, STE, software**
- **Shipping containers arrangements, modification**
- **Contingency plans**
- **Attitude control & orbit determination software set-UP**
- **S/C functional model development**
- **Data analysis**
- **Discrepancy generation, investigation, tracking, & closeout**
- **Test & S/C closeout & certification**
- **Test conduct**

LP AI&T Requirements

Integration and Test

LOCKHEED MARTIN

Paragraph	Paragraph Title	Verification Method
3.1.1	Function	A, SO
3.1.2	S/C Coordinate System	SA
3.1.3	Spin Stabilization	A, SB
3.1.4.1	S/C to Launch Vehicle	I
3.1.4.2	S/C to ST's	I, D
3.1.4.3	S/C to Ground System	I, D
3.1.4.4	TLI Stage to S/C and LV	I, D
3.1.4.5	Payload Shroud	A, S
3.1.4.6	Separation Signaling	D
3.2.1	Launch	A, I
3.2.2	S/C Activation	A, I
3.2.3	Trans-Lunar Cruise	A, I
3.2.4	Mid-course Correction Maneuver	A, I
3.2.5	Lunar Orbit	A, I
3.2.5.1	Lunar Orbit Insertion Maneuver	A, I
3.2.5.2	Lunar Orbit Maintenance	A, I
3.3.1	Launch Loads	A, SC, SS
3.3.2	Earth Orbit	A
3.3.3	Translunar	A, ST
3.3.4.1	Nominal Dayside/Nightside Conditions	A, ST
3.3.4.2	Lunar Eclipse Conditions	A, ST
3.4.1	Structures and Mechanisms	A, I, SM, SS
3.4.1.1	External Structure	A, I
3.4.1.2	Equipment Shelf	A, I
3.4.1.3	Triangular Support Structure	A, I
3.4.1.4	TLI Stage Adapter	A, I
3.4.1.5	Instrument Masts	A, I
3.4.2	Electrical Power	A, D
3.4.2.1	Solar Array	A, SF, D
3.4.2.2	Battery	A, SF, D
3.4.2.3	Power Distribution	I, D
3.4.2.4	Electrical Circuits and Components	I, D
3.4.3	Thermal Control	A, ST
3.4.3.1	Spacecraft Bus	A, ST
3.4.3.2	Scientific Instruments	A, ST
3.4.4	Communications	A, S
3.4.4.1	S-Band Transponder	A, S
3.4.4.2	Communications with Tracking Stations	A, S
3.4.4.3	Transponder Functions	A, D, S
3.4.4.4	Medium Gain Antenna	D, S

LP AI&T Requirements (cont'd)

Integration and Test

LOCKHEED MARTIN

Paragraph	Paragraph Title	Verification Method
3.4.4.5	Low Gain Antenna	D, S
3.4.4.6	Doppler Tracking	D, S
3.4.5	Command and Data Handling	A, D, S
3.4.5.1	Near and Far Side Operations	D, S
3.4.5.2	Uplink to Spacecraft	A, S
3.4.5.3	Uplink Command Protocol	D, S
3.4.5.4	Commands For Immediate Execution	D, S
3.4.5.5	Stored Commands	D, S
3.4.5.6	Downlink From Spacecraft	D, S
3.4.5.7	Downlink Telemetry Structure	D, S
3.4.5.8	Command Uplink and Downlink Bit Rate	A, D, S
3.4.5.9	System Timing and Synchronization	D, S
3.4.6	Attitude Control	A, D, S
3.4.6.1	Sun Position Determination	A, D, S
3.4.6.2	Limb Crossing Data	A, D, S
3.4.6.3	Spin Period Determination	A, D, S
3.4.6.4	Nutation Damping	D, S
3.4.7	Propulsion	A
3.4.7.1	Thrusters	A, D
3.4.7.2	Thruster Utilization	A, D, S
3.4.7.3	Propellant Tanks	A
3.5.1	Mass Allocation	SW
3.5.2	Distribution Voltage	A, D
3.5.3	Power Allocation	A, S
3.5.4	Radiation	I
3.5.5	Magnetic Field	D

LUNAR PROSPECTOR INTEGRATION AND TEST PLAN

1.0 Purpose

The purpose of this plan is to delineate the integration and test planning activities required to support Phase C/D of the Lunar Prospector (LP) Spacecraft Integration and Test Program. This plan is submitted in support of the LP Phase B Assembly, Integration, Test, and Checkout detailed plan development.

2.0 Scope

This plan defines the LP component and spacecraft qualification and acceptance test programs as well as the spacecraft structural test qualification program. This plan also addresses end-to-end compatibility tests using the LP operational system. All communication to the spacecraft in the end to end tests will go through the LP Operations Control Center, which controls the in-flight LP spacecraft and receives its telemetry. This document also discusses planning for subsystem and flight system hardware/software test beds, mechanical and electrical special test equipment (MSTE and ESTE), and launch site support activities.

3.0 LP Test Program

3.1 Test Program Approach

The Integration and Test approach used throughout this document is based on requirements of the Lunar Prospector Mission, NASA Discovery-Class Mission Guidelines, and Lockheed Martin Space Systems Division baseline test program guidelines. The LP test program/approach is summarized by the following:

Component Test Program	Test program based upon NASA/LMSC requirements/guidelines. Objective is to provide qualified/tested hardware for the spacecraft. Development testing is performed as required.
Subsystem/EM Test Program	Provides additional confidence that bus subsystems/equipment modules (EM's) are ready to support integrated spacecraft tests.
Breadboard Test Lab	Test bed for Command and Data Handling breadboard hardware and interface checks to instruments. Used for flight and test software development, ground control and orbit maneuver testing. Available to check out LP procedures prior to use on the spacecraft.
Protoflt Spacecraft Test Program	Spacecraft used for all-up systems level flight hardware and on-board software qualification and environmental response model validations. Protoflight qualification environmental test levels and duration's are specified.

Spacecraft Acceptance Test Program	Balance of the spacecraft in the LP test program undergo complete functional and limited performance verifications. Selected environmental testing is imposed at acceptance test levels. Environmental testing is imposed to uncover latent design and workmanship problems.
End-To-End Tests	LP Operations Center compatibility, Mission Simulation, and Ground Segment End to End tests are part of the test program to assure Ground Segment readiness to support LP spacecraft. Tests are part of both the Protoflight and Acceptance Test Programs.

3.2 Test Program Summary

Table 3.2-1 is a overview of the LP test program from component to spacecraft. It summaries the various tests planned for the (1) spacecraft bus component test program, (2) spacecraft bus subsystem test program, (3) spacecraft protoflight test program, and (4) spacecraft acceptance test program. Table 3.2-2 summarizes the plan for satisfying the spacecraft/ground segment end to end tests.

3.3 Spacecraft Terminology

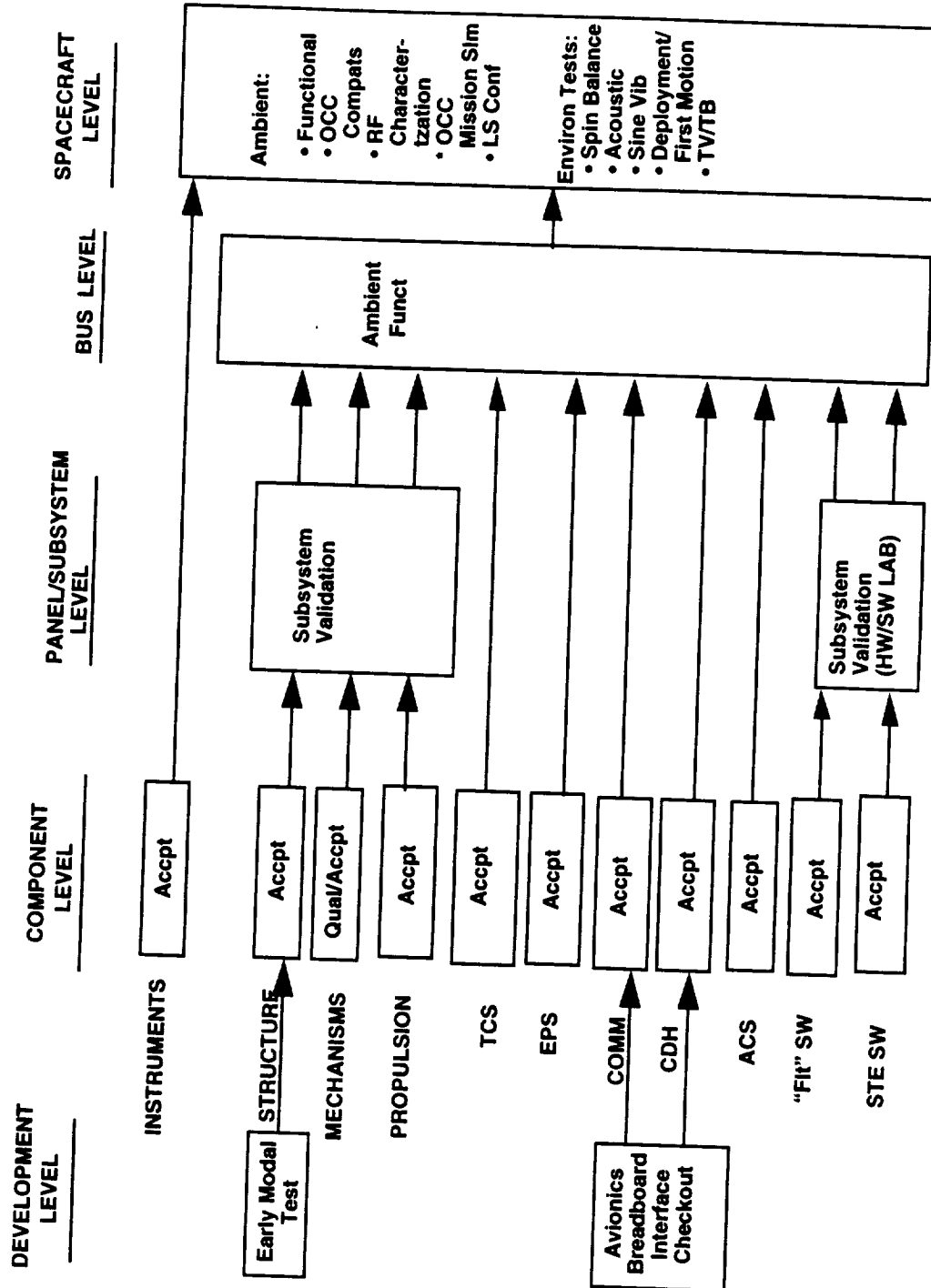
The LP spacecraft consists of a spacecraft bus with scientific instruments on three booms. The "spacecraft bus" consists of a bus structure, Mechanisms, Electrical Power subsystem, Communications, Command and Data Handling, Propulsion, Thermal Control Subsystem, and Science Instruments booms.

Figures 3.3-1 is a illustration of the LP spacecraft. Figure 3.3-2 is a functional block diagram of the spacecraft.

LP Test & Verification Program

Integration and Test

LOCKHEED MARTIN



LP Test Objectives

Integration and Test

LOCKHEED MARTIN

TEST	TEST OBJECTIVES
Ambient Functional Tests: Bus Functional S/C Baseline Functional S/C Post Acoustic Functional S/C Post TV/TB Functional Extended Power On Functional Launch Site Confidence Test	Verify the ability of the bus to support S/C level tests prior to integration to payload assembly. Verify proper operation of the spacecraft subsystems/instruments for all spacecraft modes. Same as S/C baseline functional. Same as S/C baseline functional. Verify the ability of the LP spacecraft to function over extended periods of being powered on and performing periodic mission-expected functional switching. Verify spacecraft health after shipment to WTR.
Compatibility/Mission Simulation Tests: OASIS OCC Compats Test OASIS OCC Mission Simulation Test	Verify ability of OASIS to generate LP commands and process/display engineering status data. Verify ability of OASIS to execute typical bus maneuvers/instrument operational scenarios.
Environmental Tests: Acoustic Test TV/TB Spin Balance Test Fixed Base Modal Test Sine Vibration Test	Verify proper S/C operations after simulating LLV 2 acoustic launch environment. Verify S/C operation at expected extremes in simulated lunar mission environment. Verify thermal model for S/C for the extremes expected appropriate to a lunar mission. Establish the ballast requirements to provide a spacecraft with mass properties within the limits required for spin stabilization. Determine LP spacecraft moments of inertia for the ballasted stowed LP spacecraft. Verify analytical model adequately represents the dynamic characteristics of the system and the design loads derived from the model are adequate. Qualify the spacecraft against sustained oscillations due to booster main engine cutoff (MECO) induced oscillations and/or booster fuel induced pogo oscillatory effects. Provides a dynamic low frequency data base to validate spacecraft dynamic design models.

LP AI&T Overview

— Integration and Test

LOCKHEED MARTIN

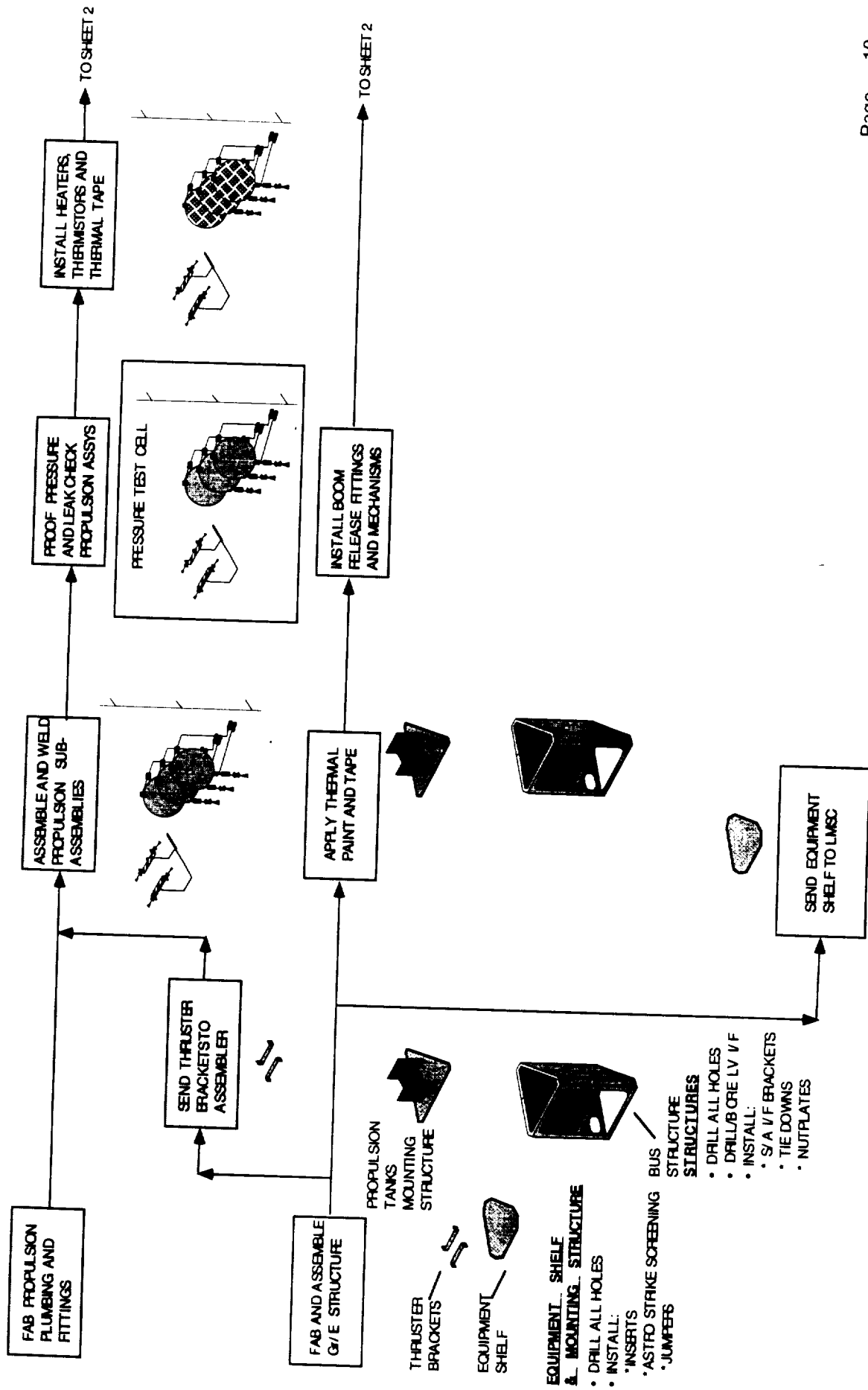
- Planning, procedure, ground support equipment, shipping, and facility interconnections built upon IRIDIUM® commercial program leading development, design, and implementation
 - RESULT: Reduced schedule risk, cost, and cycle time
- Test system, test software, database, data analysis tools, and mission operations system using NASA standard OASIS system with the CRSS commercial program and RISE independent development implementation and personnel
 - RESULT: Reduced schedule risk and cost, minimized transition from test to operations, and immediate personnel productivity toward task accomplishment
- LP spacecraft with simple and standard interfaces, limited redundancy and cross-strapping, and uncomplicated spacecraft operations
 - RESULT: efficient assembly, integration, test, and analysis

LP Core Vehicle Assembly Sequence

(1 of 2)

Integration and Test

LOCKHEED MARTIN

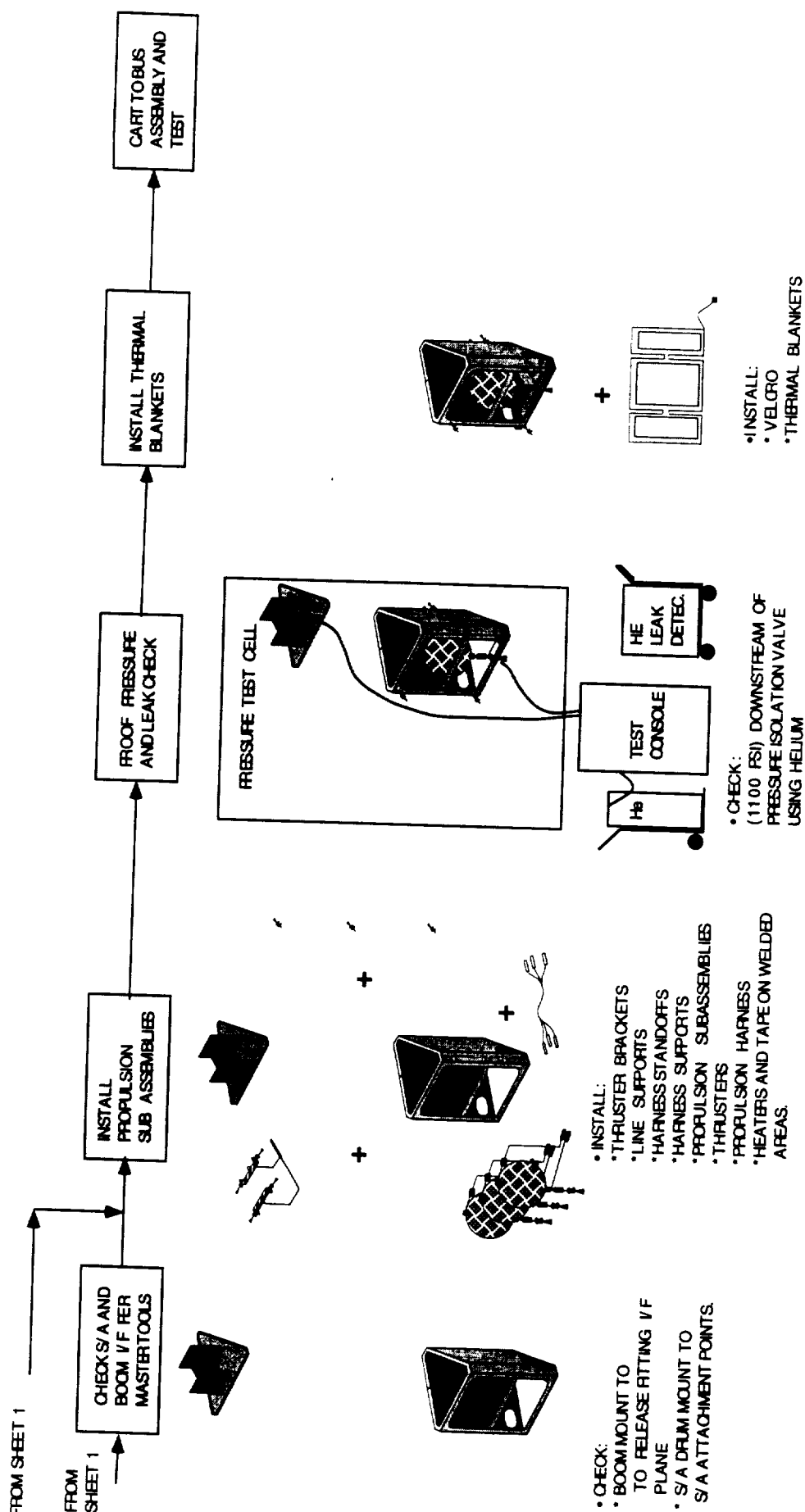


LP Core Vehicle Assembly Sequence

(2 of 2)

Integration and Test

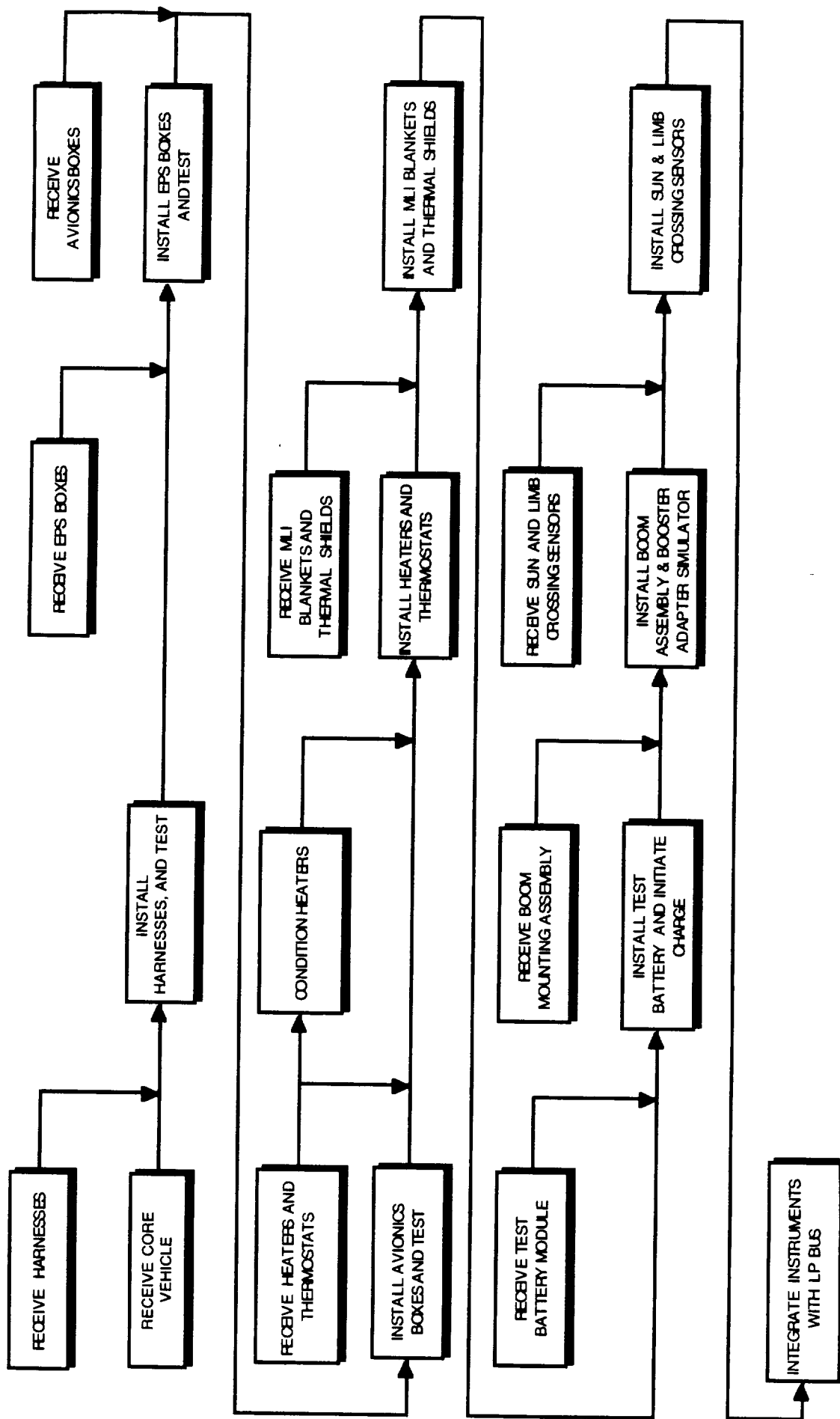
LOCKHEED MARTIN



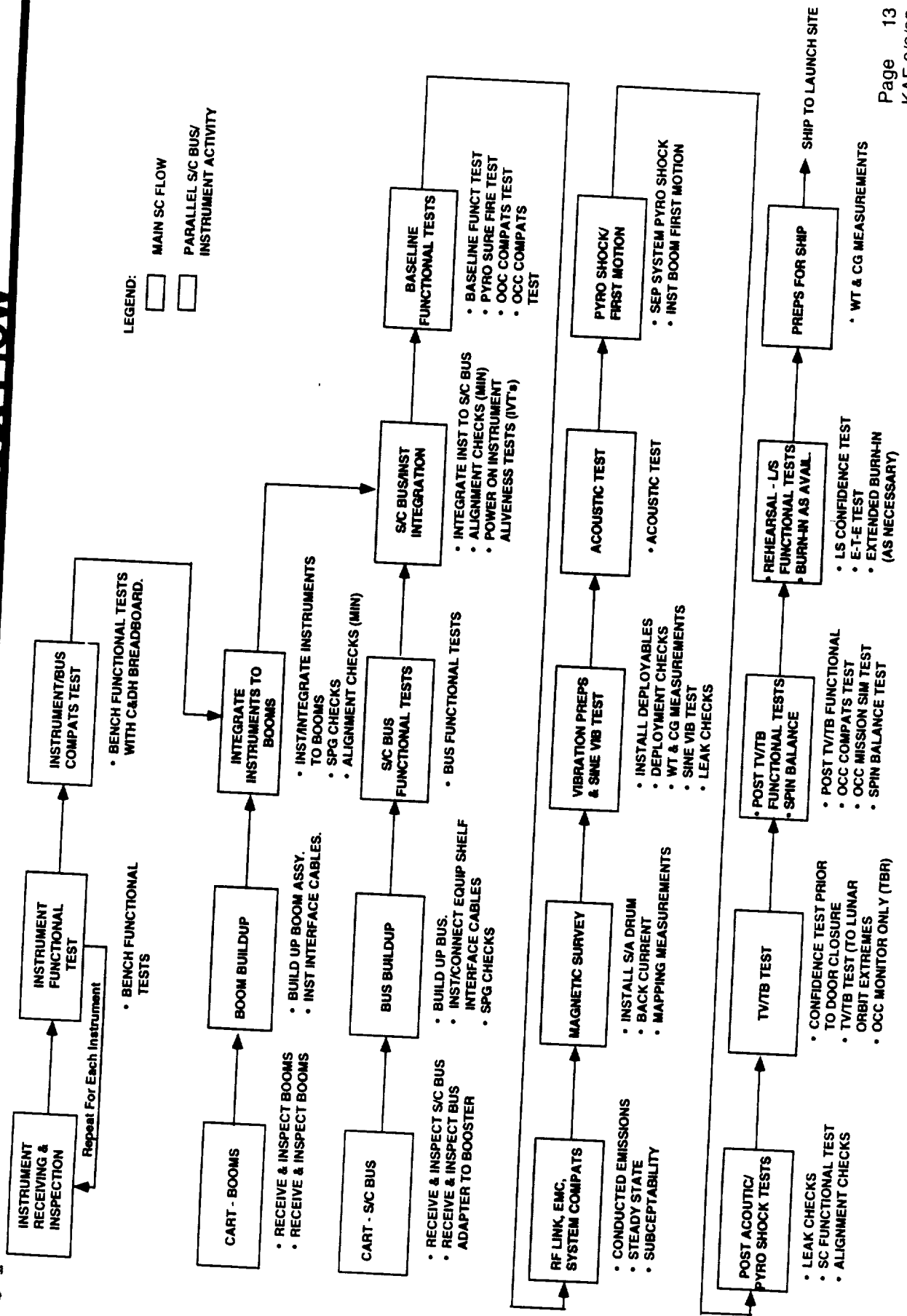
LP Bus Assembly Sequence

LOCKHEED MARTIN

Integration and Test



Assembly and Test Integration and Test Flow



ID	Task Name	Duration	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	LUNAR PROSPECTOR SYSTEM TEST & LAUNCH	186d															
2	LAUNCH																
3	Development Fixed Base Modal Test	0d															
4	Structure Assembly with Plumbing Installed	28d															
5	Box Installation/Housewire Installation (Harness)	0d															
6	Preliminary TSW Required	28d															
7	Lunar Prospector Spacecraft Bus Functional	0d															
8	Connect STE to Spacecraft	32d															
9	Perform Pre-power checks	1d															
10	Perform Spacecraft Bus Functional	1d															
11	Lunar Prospector Spacecraft Assembly & Ambient Test	30d															
12	Perform Instrument Interface Check	15d															
13	Connect Instruments to Spacecraft & C/O	5d															
14	Perform RF Link Check	10d															
15	Perform System Compatibility Test	10d															
16	Perform EMC Test	10d															
17	Solar Panel Drum Assembly required	5d															
18	Perform Magnetic Survey	0d															
19	Acoustic/Leak Check/Sine Vib/Post Exposure Health Check	5d															
20	Review Data/Disconnect STE	38d															
21	Perform Preliminary Masss & CG Check	1d															
		2d															

Project: _____

Date: Thu 8/31/95

Summary _____

Rolled Up Task _____

Rolled Up Milestone _____

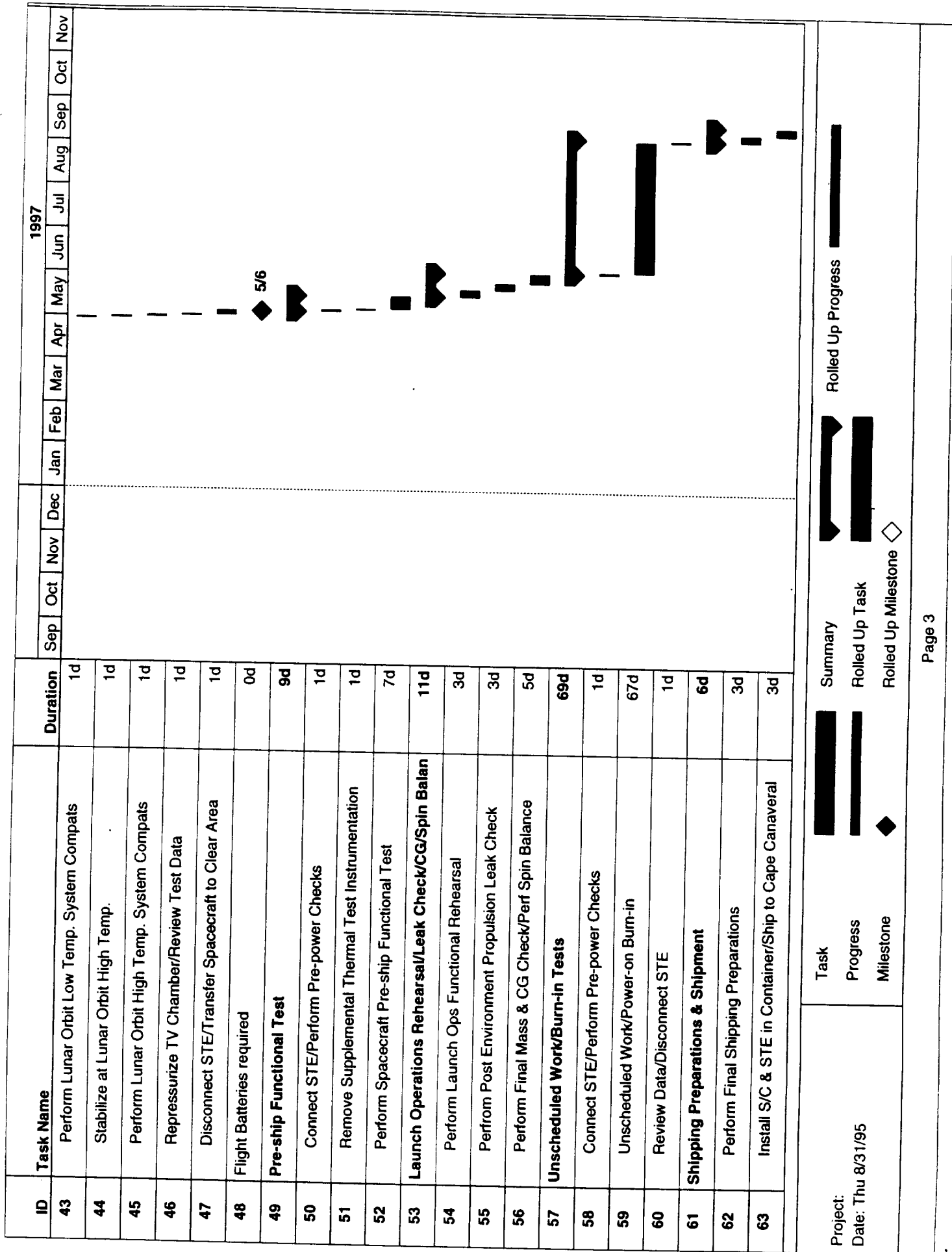
Task _____

Progress _____

Milestone _____

Rolled Up Progress _____

Page 1



ID	Task Name	Duration	1997																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
			Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
64	LP Spacecraft Arrival at the Cape	0d																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														</

◆ 9/15

◆ 10/9

Task
Progress
Milestone

Summary
Rolled Up Task
Rolled Up Milestone

Task
Progress
Milestone

Summary
Rolled Up Task
Rolled Up Milestone

Task
Progress
Milestone

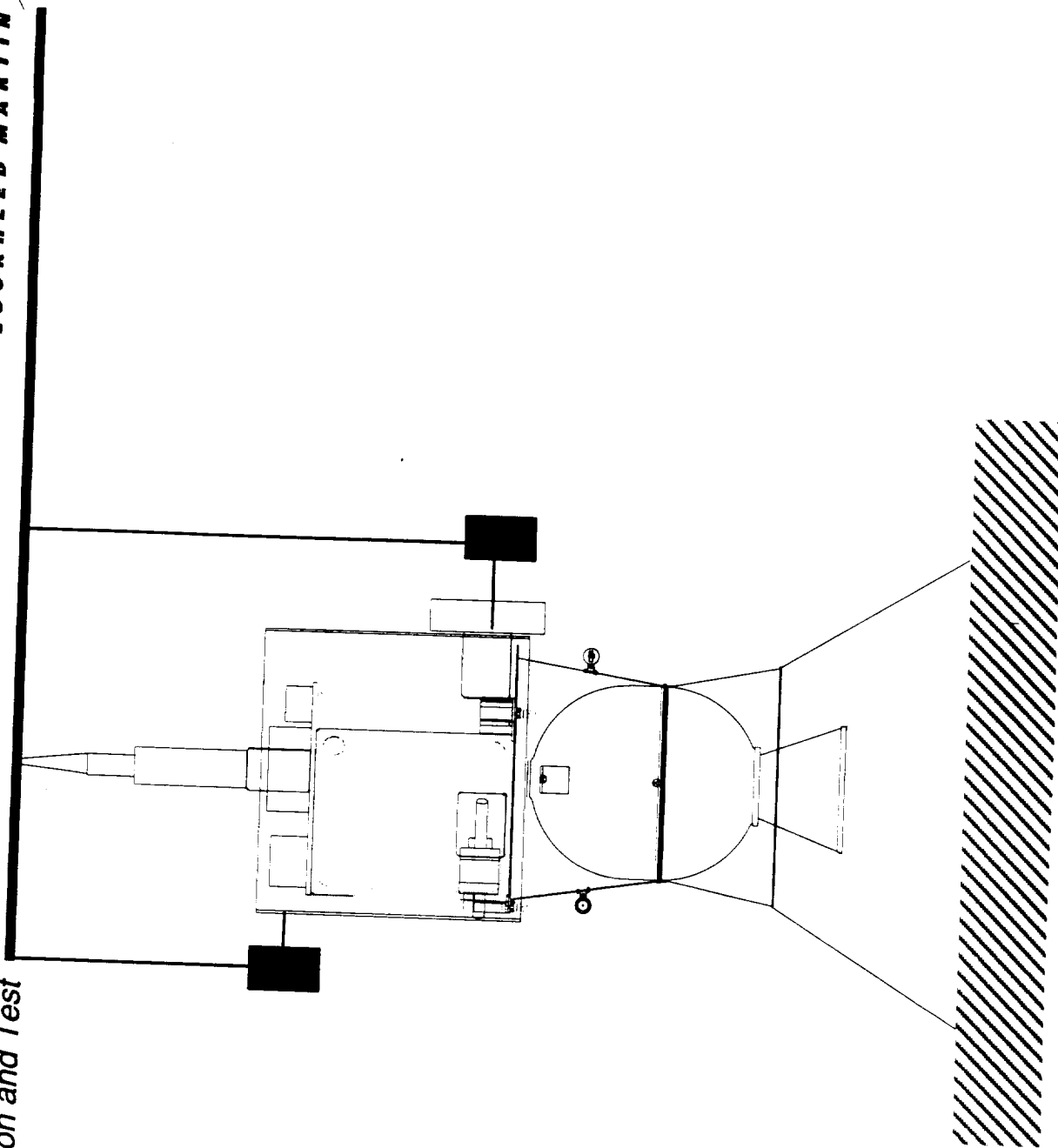
Summary
Rolled Up Task
Rolled Up Milestone

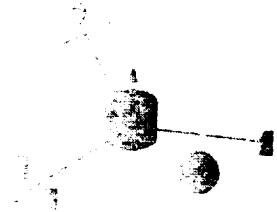
Project:
Date: Thu 8/31/95

LP Modal Test Setup

— Integration and Test

LOCKHEED MARTIN





LUNAR PROSPECTOR ENGINEERING MEMORANDUM

TITLE: LP ELECTRICAL GROUND SUPPORT EQUIPMENT REQUIREMENTS AND DESIGN CONCEPTS			EM NO: AIT&C 001 DATE: 21 August 1995 REVISED:	
AUTHOR(S) George Dankiewicz	PHONE: 2-8343	ORGN: 64-30	APPROVALS: (AIT&C Mgr) _____ (System Engr) _____ (Program Mgr) _____	

SUMMARY:

This EM presents the Electrical Special Test Equipment (ESTE) requirements and design concepts for Lunar Prospector Spacecraft factory/launch site testing and support. All designs are based on LP defined and derived requirements. The test system is designed to support remote spacecraft testing (factory and launch site) and interface with scientific instrument STE (TBD). The ESTE design philosophy is to maximize the use of existing/similar designs and to use commercially available items where possible to reduce cost and risk.

1.0 INTRODUCTION

The basic core Electrical Special Test Equipment (ESTE) will be an OASIS automated test system with a centrally located Test Control Center (TCC) where tests are controlled and engineering status data is evaluated in real time. Spacecraft support equipment, which interface directly with the LP spacecraft, are relocatable and move with the spacecraft as the test location changes. The LP Test System Concept block diagram is provided in figure 1.0-1. Science data will be evaluated either in near real time (quick look - tbd) or post test (off line). The test system will be the workstation based OASIS system developed by the University of Colorado and will maximize the use of commercial off-the-shelf (COTS) hardware and employ industry standard interfaces throughout. The test system will be based on the OASIS provided Colorado System Test and Operation Language (CSTOL) software.

The proposed automated test system is divided into three major groups of equipment: (1) Test Control Center, (2) Spacecraft Support Consoles, and (3) Ancillary Test Equipment.

2.0 TEST CONTROL CENTER

2.1 Requirement

A test system shall be provided to validate the LP spacecraft during factory and launch site testing.

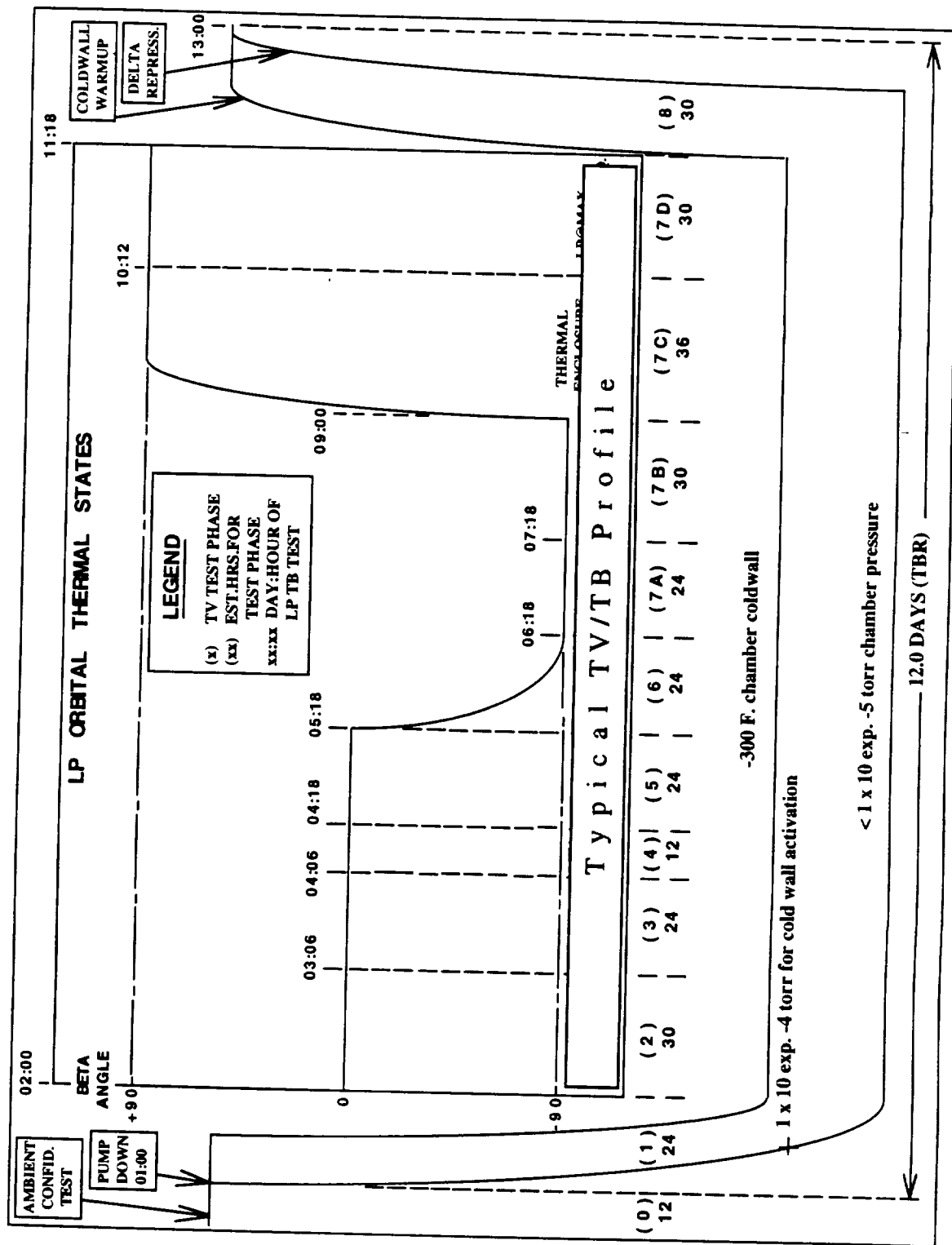
The spacecraft integration and test special test equipment (STE) shall support the exchange of command and telemetry data with the LP spacecraft.

The test system shall support end-to-end testing through the Lunar Prospector Operations and Control Center.

LP TV Test Profile

Integration and Test

LOCKHEED MARTIN



LP Facilities

Integration and Test

LOCKHEED MARTIN

FACILITY

- B/150 HB

FUNCTIONS/FEATURES

- ASSEMBLY
- AMBIENT TESTS

ALTERNATIVE(S)

- B/156F
- B/104

• B/156C	- ACOUSTIC CELL (#2)	B/156C #1
• B/158	- DELTA CHAMBER	B/151 STARS
	- \$1M UPGRADE COMPLETE	B/156A A-1
	- THERMAL VACUUM/THERMAL BALANCE	B104 VEGA/ HIVOS
• B/104 SBF	- SPIN BALANCE FACILITY	B/104 VSBF**
• B/107 TB	- LP HARDWARE SOFTWARE INTEGRATION FACILITY	B/150 BFTF
• B/102	- STRUCTURAL TEST FACILITY	
	- THREE SELF-REACTING TEST STANDS IN HIGH BAY	
• B/564	- PROTOTYPE LAB (DISPLAYS & SOFTWARE)	
	- USE NOT ENVISIONED AT THIS TIME	
• B/076	- ANECHOIC CHAMBER	
	- ELECTROMAGNETIC SELF COMPATIBILITY	
	- USE NOT ENVISIONED AT THIS TIME	

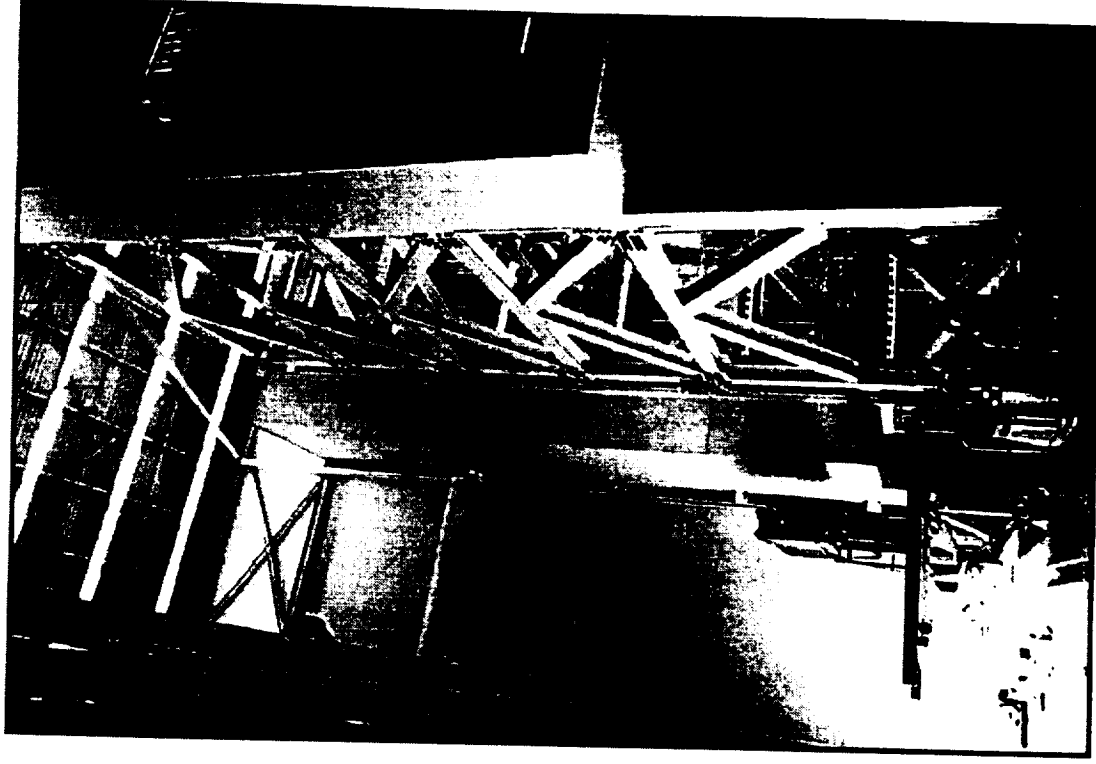
Structural Test Lab Buiding 102

— Integration and Test

LOCKHEED MARTIN

- Two self-reacting test stands located
In high-bay area
 - 16 ft² and 20 ft² base plates
 - 60-ft high reaction structures
 - 4-in. steel base plates with concrete
- Adjacent low-bay area with reaction
Track floor
- 36,000-force-lb and 17,000-force-lb
Environmental generating systems
- Sinusoidal and random
Environmental control system
With shaker shock synthesis
- Mechanical and pyro shock simulation
- Two control/data acquisition
Systems
- Data analysis and reduction
Systems with x-y, psd, and
Shock spectrum plots

M99.02



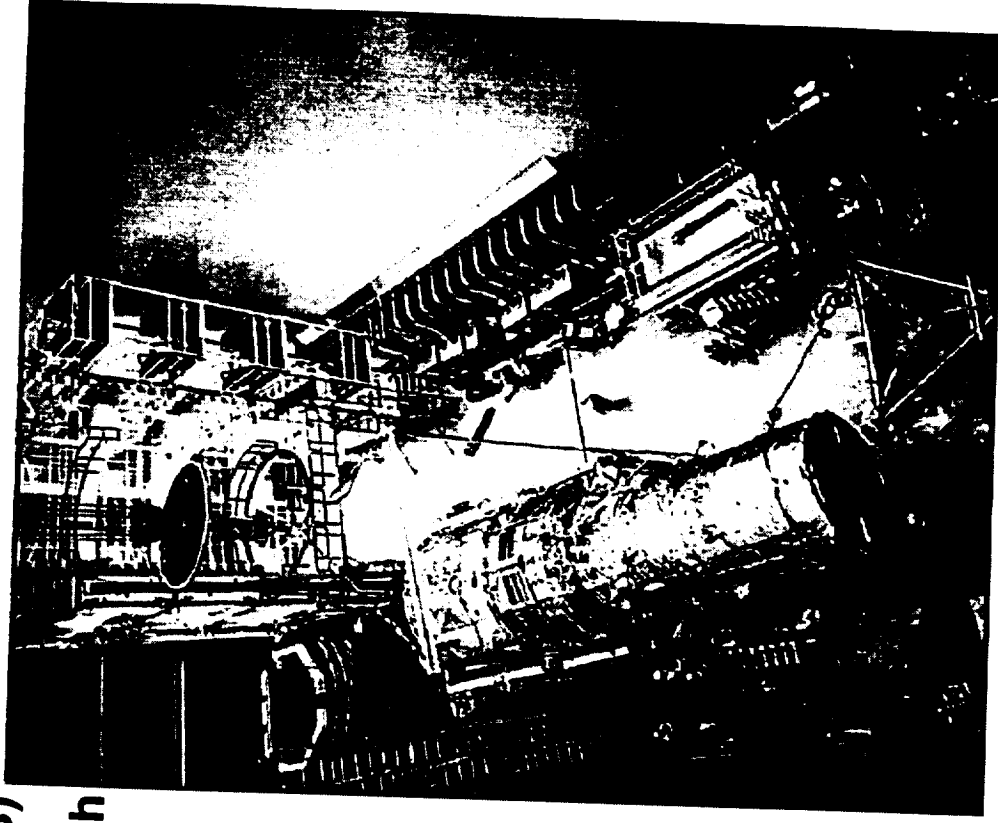
Integration and Test Cleanroom Building

156F

— Integration and Test

LOCKHEED MARTIN

- **Class 10,000 cleanroom (FED-STD-209B)**
- **SIZE: 55-ft wide x 120-ft deep x 90-ft high**
- **55-Ft x 90-ft high-efficiency particulate Air (hepa) filter wall**
- **Horizontal laminar flow**
- **Hepa filters capable of filtering Out 99.997% Of particles greater Than 0.3 Microns**
- **20-TON bridge crane, 76-ft hook height**
- **Fire prevention system that utilizes Dry delivery piping with water flow Controlled by system prevalve**
- **Cleanroom sized to permit Processing of two spacecraft**
- **Built-in contamination monitoring And purge system**



M99.09

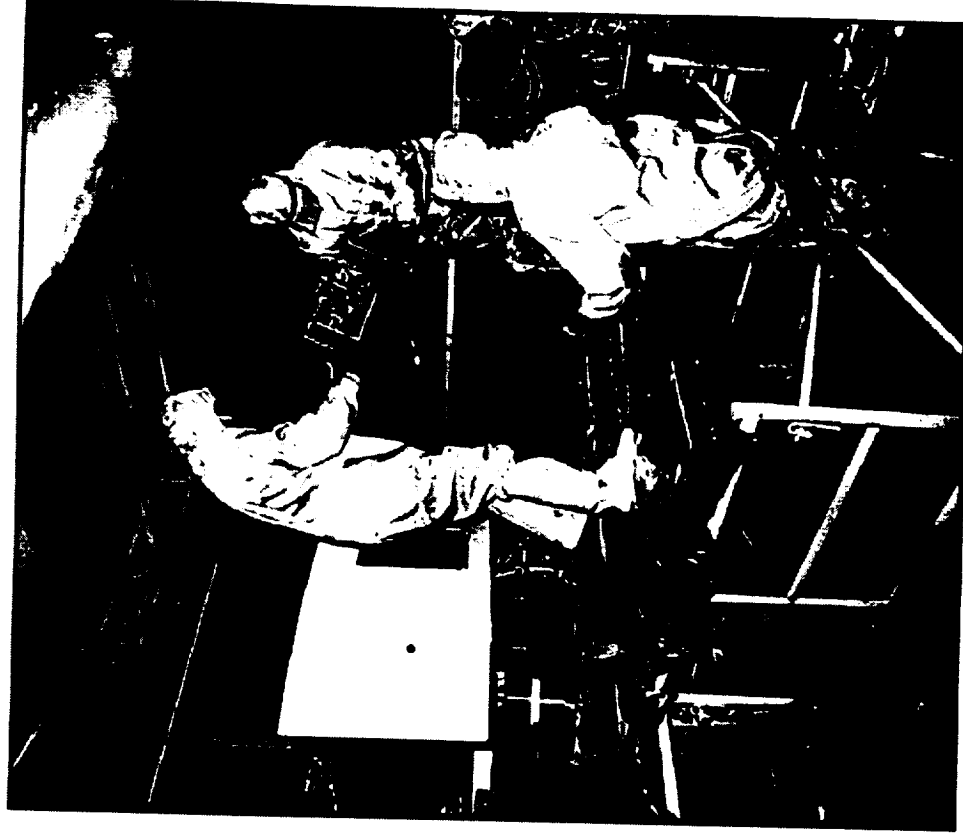
Instrument Receiving and Inspection Depot Building 156F

— *Integration and Test*

LOCKHEED MARTIN



- **Class 100,000 cleanroom**
- **SIZE: 40-ft wide x 50-ft deep**
- **Class 10,000 laminar flow booths
For instrument inspection and test**
- **Accommodates instrument test team
Personnel and associated GSE**
- **Located adjacent to spacecraft
Integration and test cleanroom and
Science instrument data room**
- **Fire prevention system that utilizes
Dry delivery piping with water flow
Controlled by system prevalve**
- **Built-in contamination monitoring
And purge system**



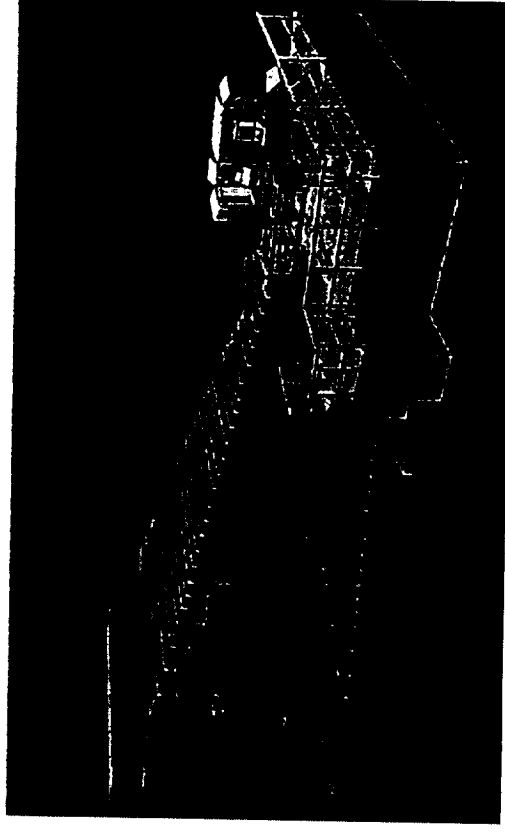
Electromagnetic Technology Center Buildings 076 and 133

— *Integration and Test*

LOCKHEED MARTIN



- Integrated antenna development, Antenna feeds, deployable and Phased-array antennas
- Rf/mechanical analysis and design
- Complete fabrication and assembly
- Complete design verification
- Two tapered antenna ranges, one Large compact and one medium Compact range
- Antenna range measurements (100 MHz TO 100 GHz)
- Special technology measurements
- Nondestructive dielectric Measurements
- Passive intermodulation Measurements
- Analyzer measurements



Acoustic Test Cell No. 2 Building 156C

— Integration and Test

LOCKHEED MARTIN

- **SIZE:** 20-ft wide x 26-ft deep x 31-ft high
- **DOOR:** 15-ft wide x 31-ft high
- **Controlled to class 100,000 cleanroom Levels**
- **Located off building 156c high bay, Adjacent to 100,000 class cleanroom**
- **15 Nitrogen gas supplied Electropneumatic noise generators**
- **156.5-Db reverberant field, 162.5-Db Direct field**
- **250,000-W acoustic power**
- **100-Hz cell low-frequency cutoff**
- **Data acquisition system with 520 Acoustic data channels and 100 pyro Shock data channels**



Lockheed Martin Missiles and Space

— *Integration and Test*

LOCKHEED MARTIN



Modal Test Lab Building 102

— Integration and Test

LOCKHEED MARTIN

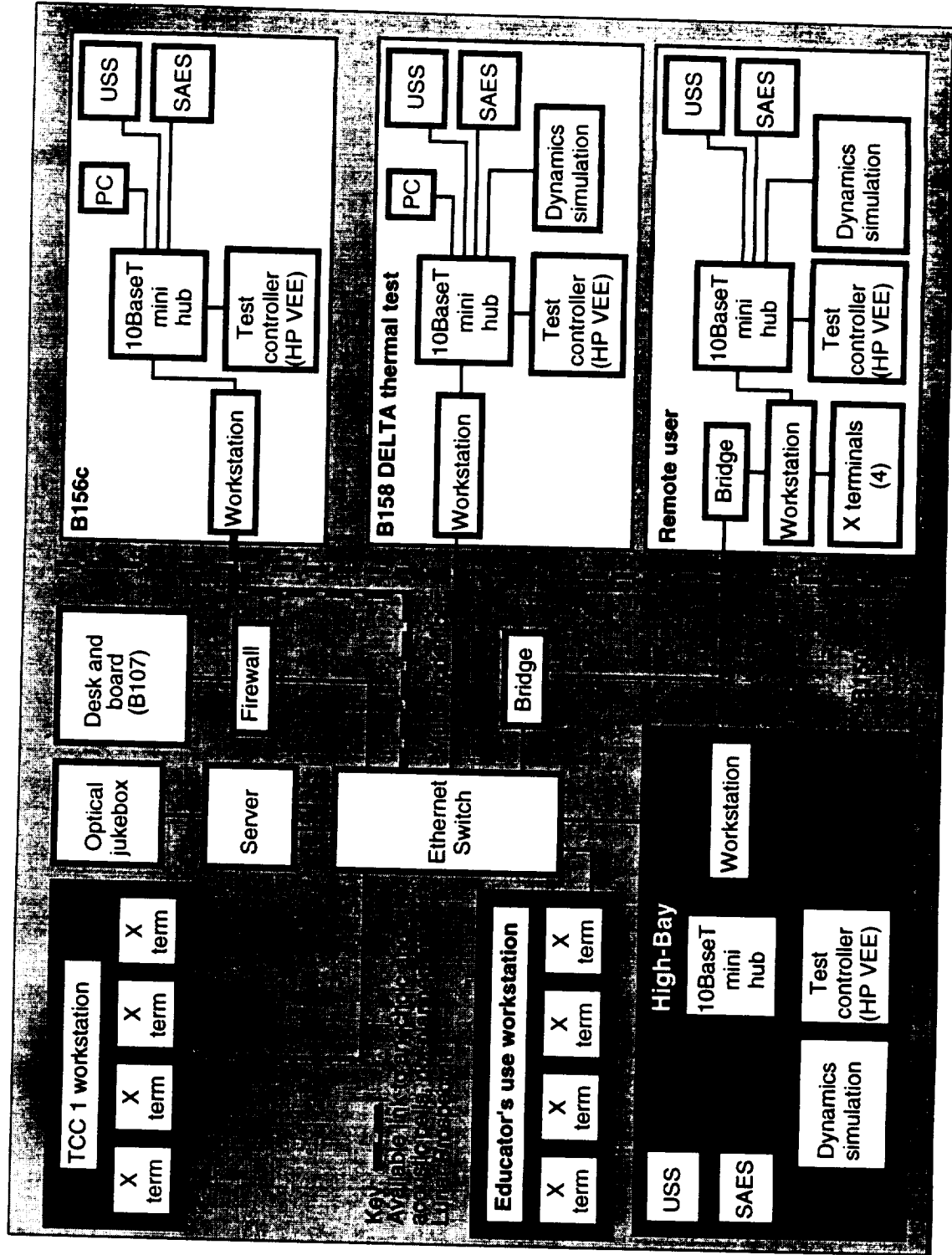
- External/integral actuator
Commanding for operational
Environment simulation
- Instrument and monitor data
Recording
- Data processing for report plots
And parameter representation
Computations
- Tests performed in a variety of
Stands and on lab floor mounts
- 10,000-Lb AND 1,500-lb capability air
Bags for free-free boundary
Conditions
- Mounting configurations developed
From existing hardware
- Custom hardware fabrication
Capability



Systems Test Facilities Interlink

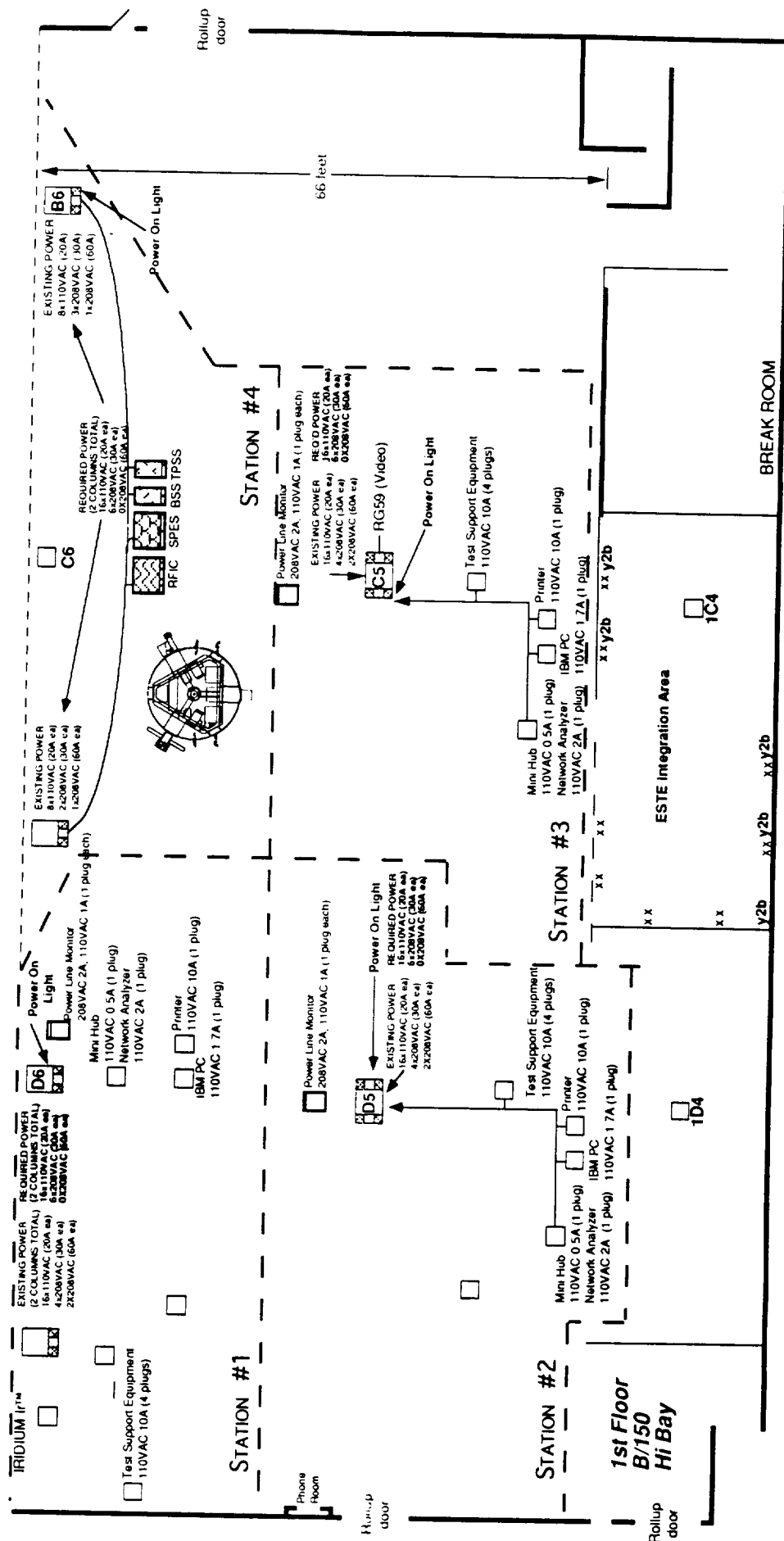
— Integration and Test

LOCKHEED MARTIN



LP B/150 Highbay Test Area

LOCKHEED MARTIN



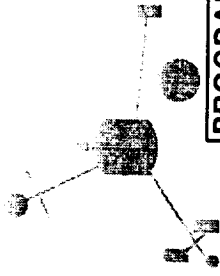
LP GSE Use & Status

— Integration and Test

LOCKHEED MARTIN

Equipment	Bus assembly	Bus funct test	Integration	S/C funct	Deploy test	Spn Balance	Mission ops test	TV	Propellant leak	Preship funct	Shipping prep	Launch ops
Solar Cells Elec Sim												
Battery Sim System												
Battery Service Unit												
Umbilical Serv Sys												
T/V Cable Set												
Prop Sys Monitor												
Test Software												
RF I/F Console												
Front End Proc												
Air Cooling Assy												
T/V Heat Flux Sim												
T/V Support Struct												
I&T Vehicle Dolly												
Integ Shipping Cont												
Shipping Cont Sling												
Integrated S/C Sling												
Therm Htr & Blkts												
Solar Cells Thml Sim												
Payload Install Sling												
T/V Feed Thru Plates												

☒ Existing (design or hardware)
☐ New or buy
☒ GFE/Instru developer provide



Lunar Prospector ESTE PHSL

Integration and Test

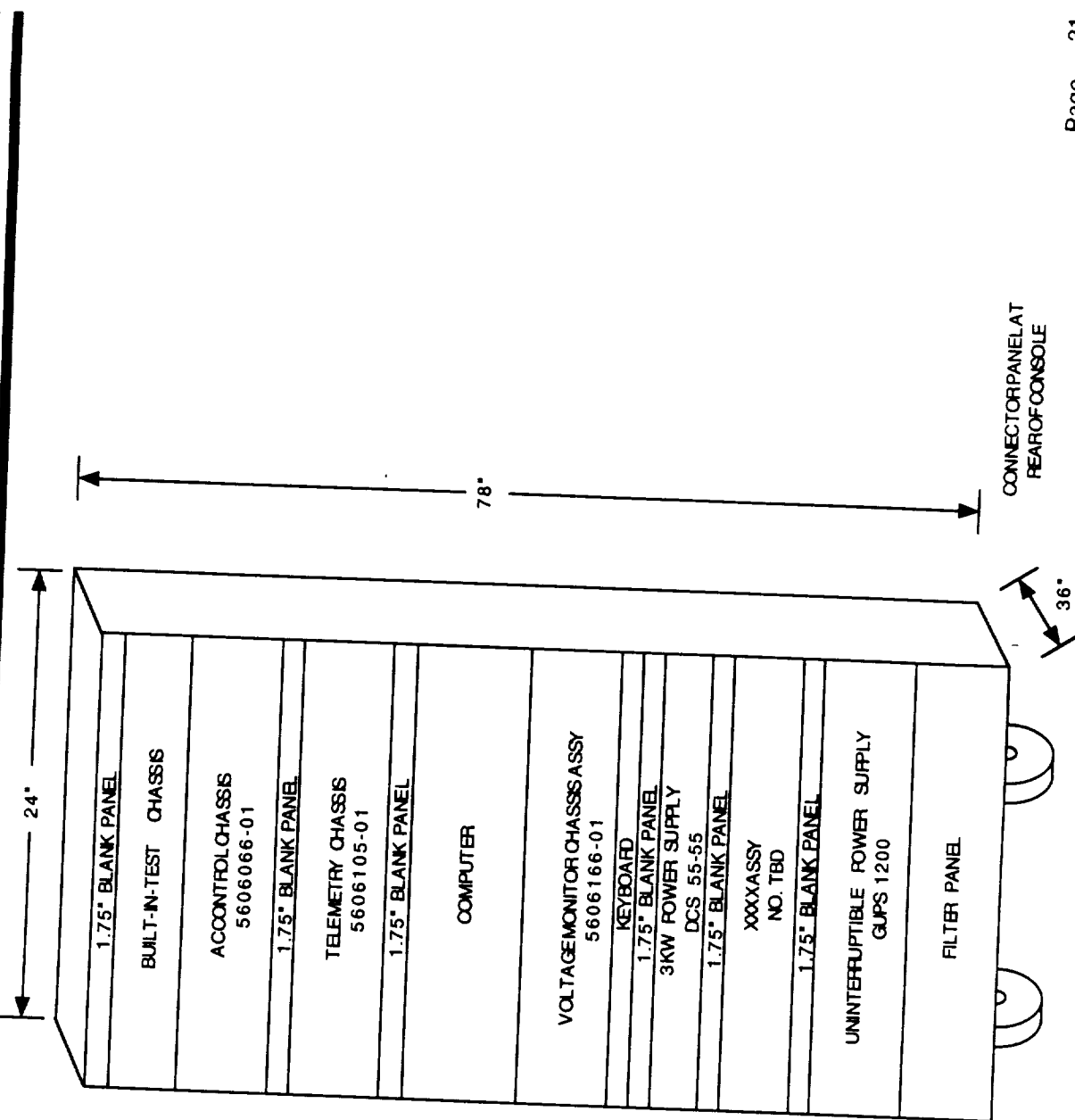
LOCKHEED MARTIN

PROGRAM HARDWARE/SOFTWARE LIST (HARDWARE)		TITLE: LP IAT&C Electrical Support & Test Equipment (ESTE) PROGRAM OFFICE APPROVAL:		DATE: 24 May 95 REVISION: A PAGE: 1 of 1
ITEM #	WBS #	NOMENCLATURE	SPEC NO.	REMARKS
1	2.1.4.5	Battery Simulator System (BSS)	F435089	Provides simulated load & I/F
2	2.1.4.5	Test Port Service System/Battery Service Unit (TPSS/BSU)	F435089	C&DH Digital I/F / ext batt supp
3	2.1.4.5	Solar Panel Electrical Simulator (SPES)	F435089	Provides simulated SAP I/F
4	2.1.4.5	Spacecraft Test System (OASIS)	COTS + custom code	Automated test capability - University of Colorado
5	2.1.4.5	Thermal Vacuum Cable Set	• IITA 1006, IITA 1007, IITA 1008, IITA 1011, IITA 1012, IITA 1013, IITA 1066, IITA 1067, IITA 1068, IITA 1075, & IITA 1079.	
6	2.1.4.5	Acoustic Cable Set	• IITA 1060, IITA, 1062, & IITA 1063.	
7	2.1.4.5	Limb Crossing Sensor Stimulator		w/ BARNES 13-210B
8	2.1.4.5	Sun Sensor Stimulator		w/ ADCOLE 21175
9	2.1.4.5	Stimulators Detector Controller		
10	2.1.4.5	Boom deployment release circuit analyzer		
11	2.1.4.5	RF Interface Console	IITA 1028 / IITA 1045 (see Tim Bridges)	
12	2.1.4.5	Antenna Hat Couplers	(see Tim Bridges)	Use BSS
Notes & Assumptions: • No test batteries required • Science Instrument standalone electrical support equipment by Instruments • Propellant System Monitoring Unit by LLV (8547327) • Radioactive Source for Instruments by Los Alamos				LS use supporting fueling

LP Test Port Service System/Battery Service Unit (TPSS/BSU)

Integration and Test

LOCKHEED MARTIN



LP GSE Data Interfaces

Integration and Test

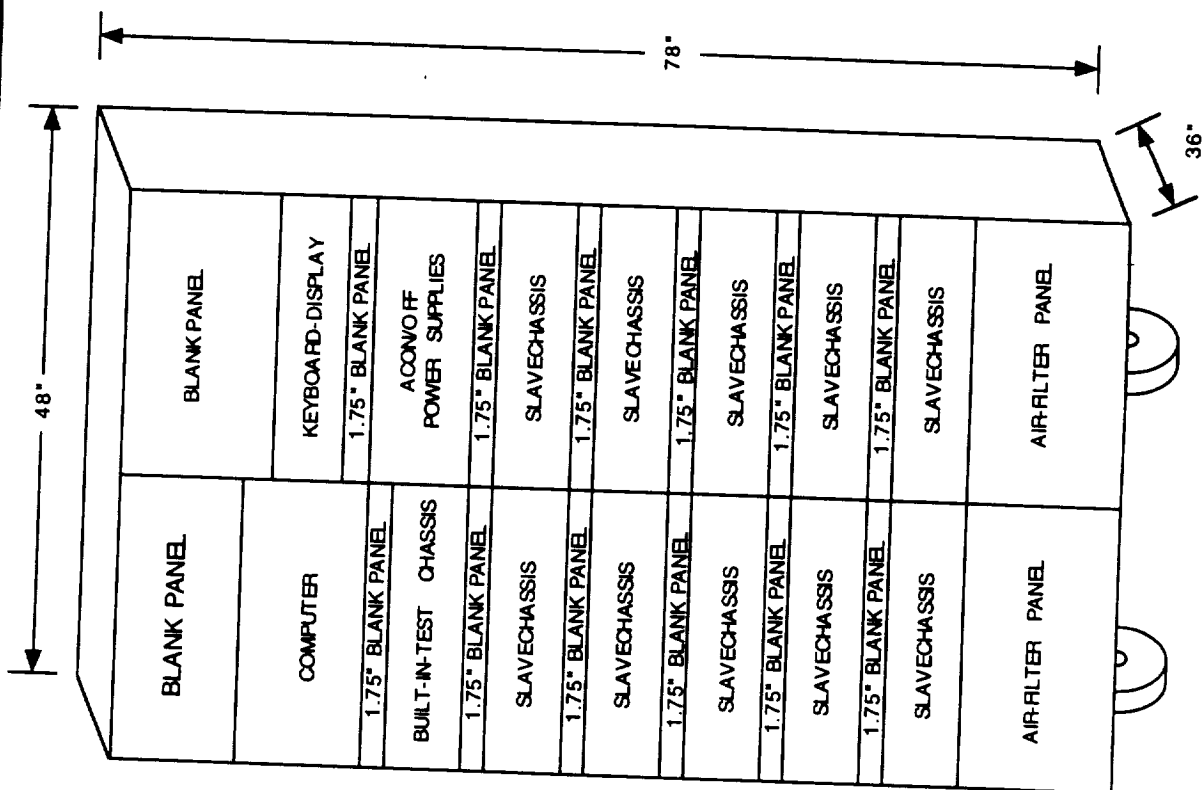
LOCKHEED MARTIN

Signal Name	Source	Destination	Signal Type	Comment	Subsystem
GSE Command #1 Data +	GSE	C&DH #1	RS-422	Differential	C&DH
GSE Command #1 Data -	GSE	C&DH #1	RS-422	Differential	C&DH
GSE Command #1 Clock +	GSE	C&DH #1	RS-422	Differential	C&DH
GSE Command #1 Clock -	GSE	C&DH #1	RS-422	Differential	C&DH
GSE Telemetry #1 Data +	C&DH #1	GSE	RS-422	Differential	C&DH
GSE Telemetry #1 Data -	C&DH #1	GSE	RS-422	Differential	C&DH
GSE Telemetry #1 Clock +	C&DH #1	GSE	RS-422	Differential	C&DH
GSE Telemetry #1 Clock -	C&DH #1	GSE	RS-422	Differential	C&DH
GSE Command #2 Data +	GSE	C&DH #2	RS-422	Differential	C&DH
GSE Command #2 Data -	GSE	C&DH #2	RS-422	Differential	C&DH
GSE Command #2 Clock +	GSE	C&DH #2	RS-422	Differential	C&DH
GSE Command #2 Clock -	GSE	C&DH #2	RS-422	Differential	C&DH
GSE Telemetry #2 Data +	C&DH #2	GSE	RS-422	Differential	C&DH
GSE Telemetry #2 Data -	C&DH #2	GSE	RS-422	Differential	C&DH
GSE Telemetry #2 Clock +	C&DH #2	GSE	RS-422	Differential	C&DH
GSE Telemetry #2 Clock -	C&DH #2	GSE	RS-422	Differential	C&DH
Receiver #1 On	GSE	C&DH #1	28 Vdc Pulse	GSE Unreg Return #1	C&DH
Receiver #1 Off	GSE	C&DH #1	28 Vdc Pulse	GSE Unreg Return #1	C&DH
C&DH #1 Comm to GSE	GSE	C&DH #1	28 Vdc Latch	GSE Unreg Return #1	C&DH
GSE Unreg Return #1	GSE	C&DH #1			C&DH
Receiver #2 On	GSE	C&DH #2	28 Vdc Pulse	GSE Unreg Return #2	C&DH
Receiver #2 Off	GSE	C&DH #2	28 Vdc Pulse	GSE Unreg Return #2	C&DH
C&DH #2 Comm to GSE	GSE	C&DH #2	28 Vdc Latch	GSE Unreg Return #2	C&DH
GSE Unreg Return #2	GSE	C&DH #2			C&DH
External Power	GSE	PCA	28 Vdc Latch	Vehicle Unreg Return	EPS
Vehicle to External	GSE	PCA	28 Vdc Latch	Vehicle Unreg Return	EPS
Battery Charge Power	GSE	PCA	28 Vdc Latch	Vehicle Unreg Return	EPS
Vehicle Unreg Return	GSE	PCA			EPS
Tank #1 Temperature	Tank #1 GSE Thermistor	GSE	Passive Analog	Tank #1 Temp Return	Thermal
Tank #1 Temp Return	GSE	Tank #1 GSE Thermistor			Thermal
Tank #2 Temperature	Tank #2 GSE Thermistor	GSE	Passive Analog	Tank #2 Temp Return	Thermal
Tank #2 Temp Return	GSE	Tank #2 GSE Thermistor			Thermal

LP Solar Panel Electrical Simulator (SPES)

— Integration and Test

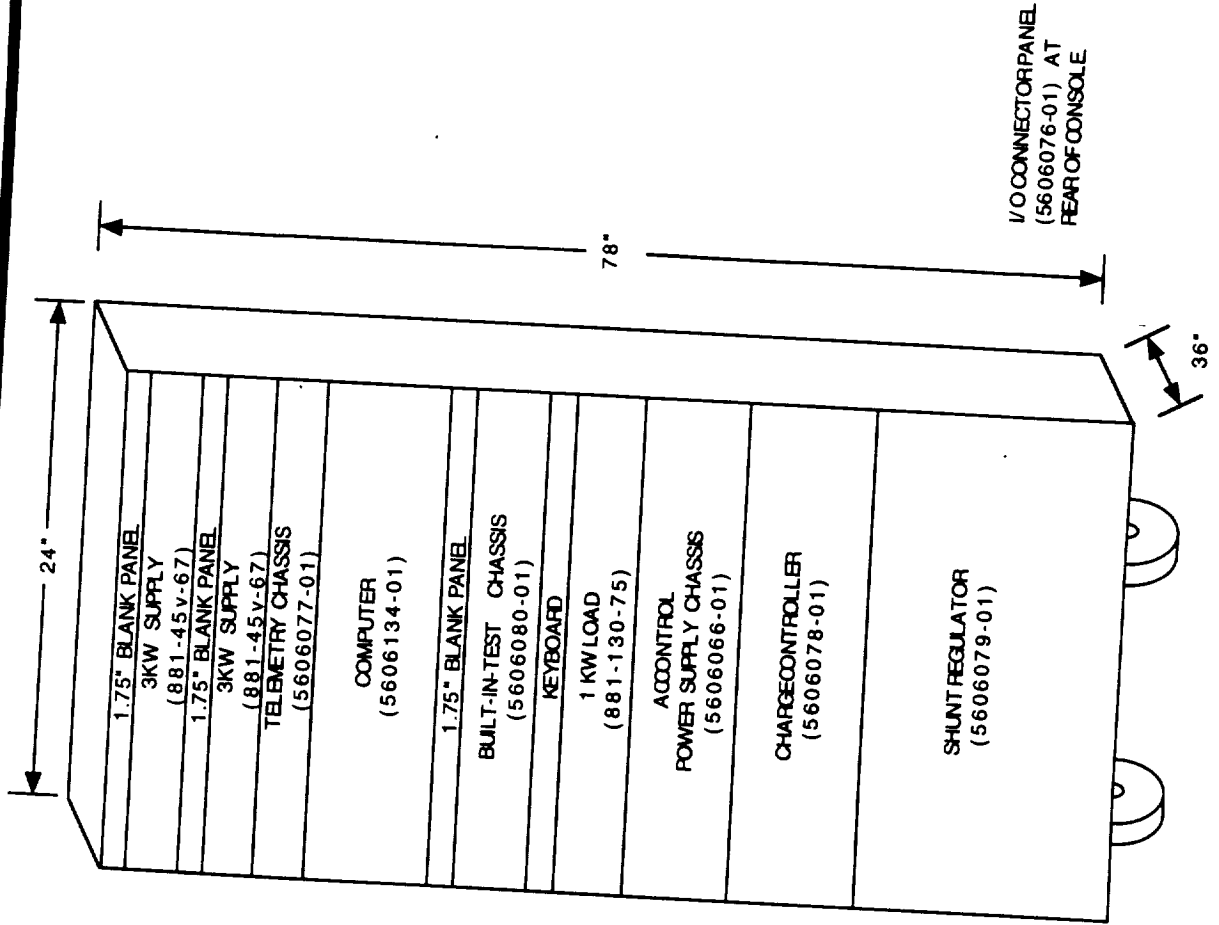
LOCKHEED MARTIN



LP Battery Simulator System (BSS)

Integration and Test

LOCKHEED MARTIN

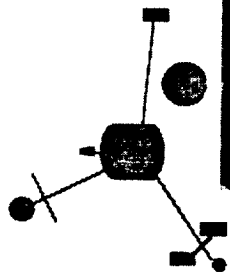


Lunar Prospector MSTE PHSL

Integration and Test

LOCKHEED MARTIN

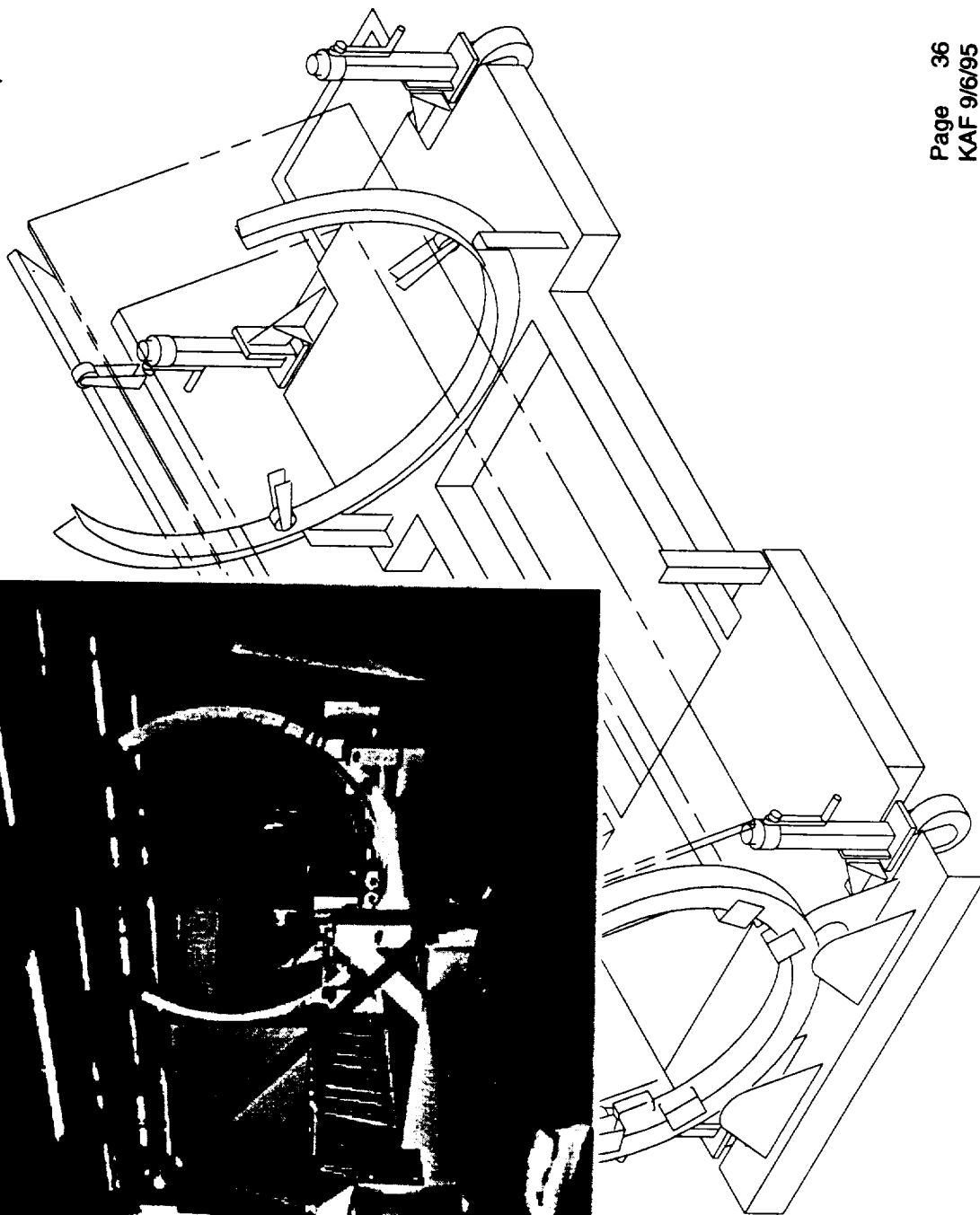
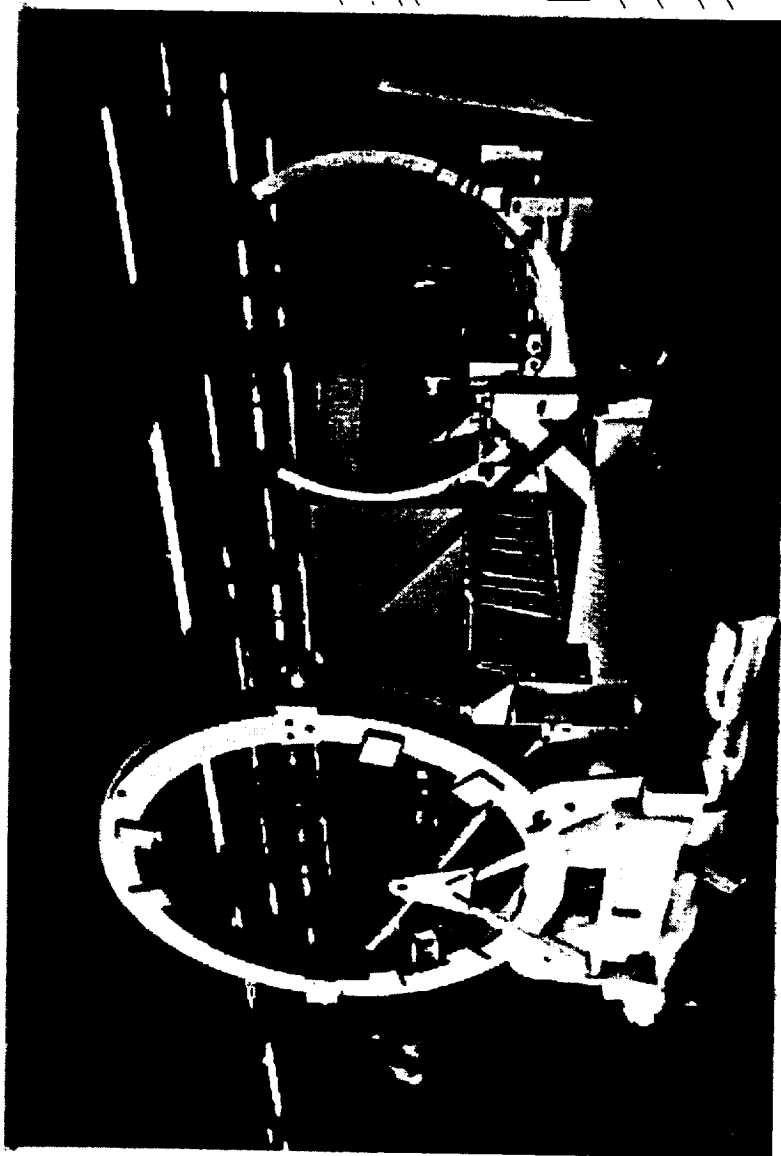
PROGRAM HARDWARE/SOFTWARE LIST (HARDWARE)		TITLE: LP IAT&C Mechanical Support & Test Equipment (MSTE)		DATE: 24 May 95
		PROGRAM OFFICE APPROVAL:		REVISION: A
				PAGE: 1 of 1
ITEM #	WBS #	NOMENCLATURE	DRAWING NO. /	REMARKS
1	2.1.4.6	Battery Assembly Handling Sling	Iridium Base	Support during handling ops
2	2.1.4.6	Electronics/Battery Air Manifold Unit	Iridium Base	Cools batt/elec during amb test
3	2.1.4.6	SC integration & transport dolly (or P368 dolly)	Iridium Base	Supports SC during sys test
4	2.1.4.6	SC Ship Container Sling	Iridium Base	Support during handling ops
5	2.1.4.6	SC Shipping Container	Iridium Base	Provides prot during trans
6	2.1.4.6	Acoustic test Fixture	Iridium Base	Supports SC during AC test
7	2.1.4.6	TV/TB Support Assembly	Iridium Base	Supports SC during TV Test
8	2.1.4.6	TV/TB Heat Flux Simulator	Iridium Base	Solar heat lamp array in TV
9	2.1.4.6	SAP Thermal Sim	Iridium Base	Therm I/F sim w/o SAP
10	2.1.4.6	Thermal Heaters & Blankets	Iridium Base	Supports TV test
11	2.1.4.6	TVC Feed Through Plates	Iridium Base	Elec I/F in/out of TV chamber
12	2.1.4.6	SC Cable Support	Iridium Base	SC cabling strain relief
13	2.1.4.6	SC Handling Sling	Iridium Base	SC support during handling
14	2.1.4.6	Boom Support Offload Device	**	Supports deployed inst booms
15	2.1.4.6	Spin Balance Support & Mounting Plate	**	Mount to B/104 spin balance
16	2.1.4.6	Instrument Clean Environment Unit	**	One per SI set on each boom
Notes & Assumptions: - Solar Array Panel Table & Dolly by EPS - Instrument Handling Units by Instruments - Propellant/Pressurant Cart by LLV - Battery Mass Simulator by EPS			Fueling cart at launch site	

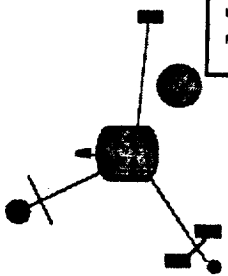


LP S/C Integration & Transport Dolly

■ Integration and Test

LOCKHEED MARTIN

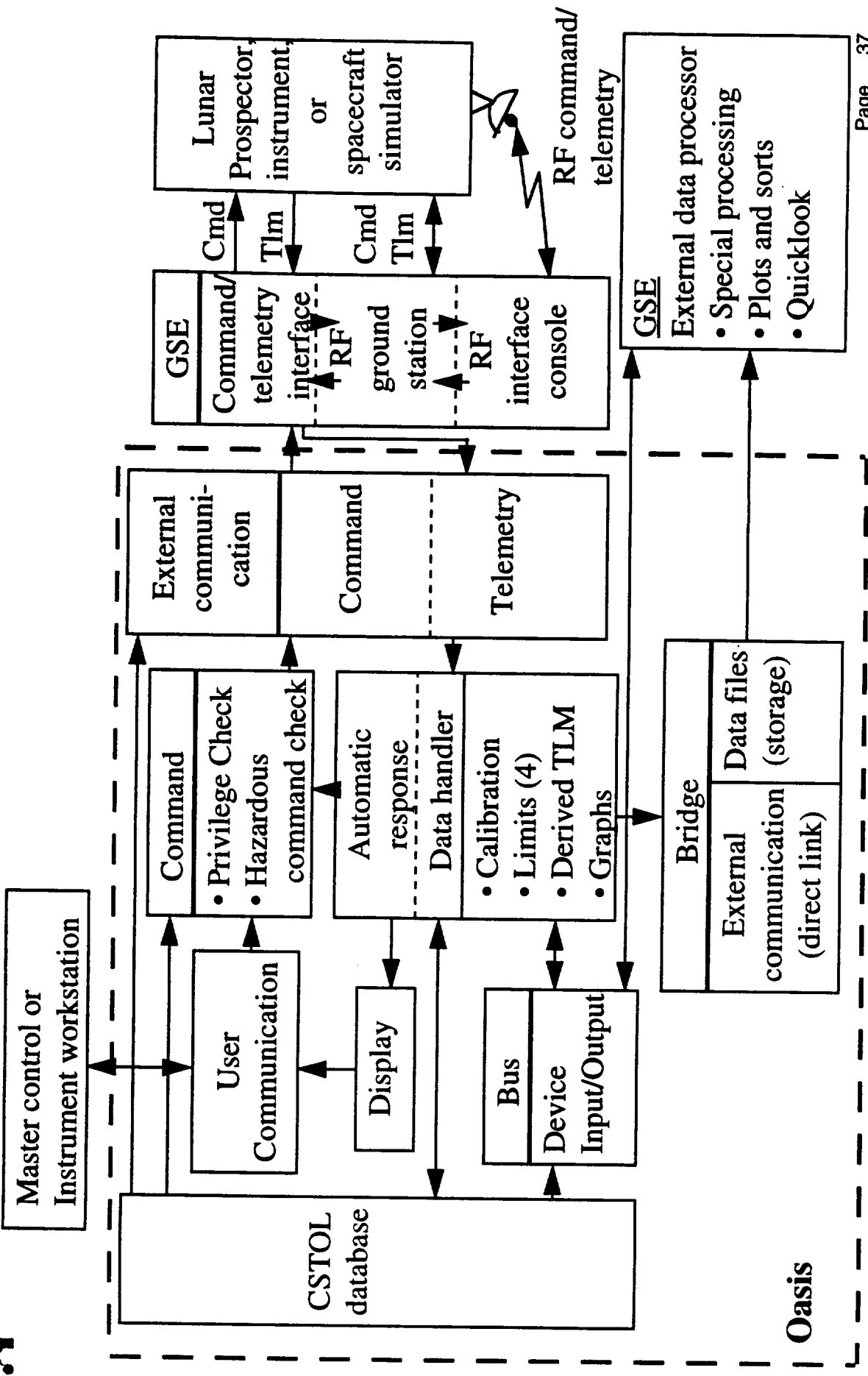


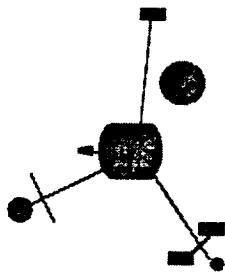


Lunar Prospector OASIS Test System

LOCKHEED MARTIN

Integration and Test

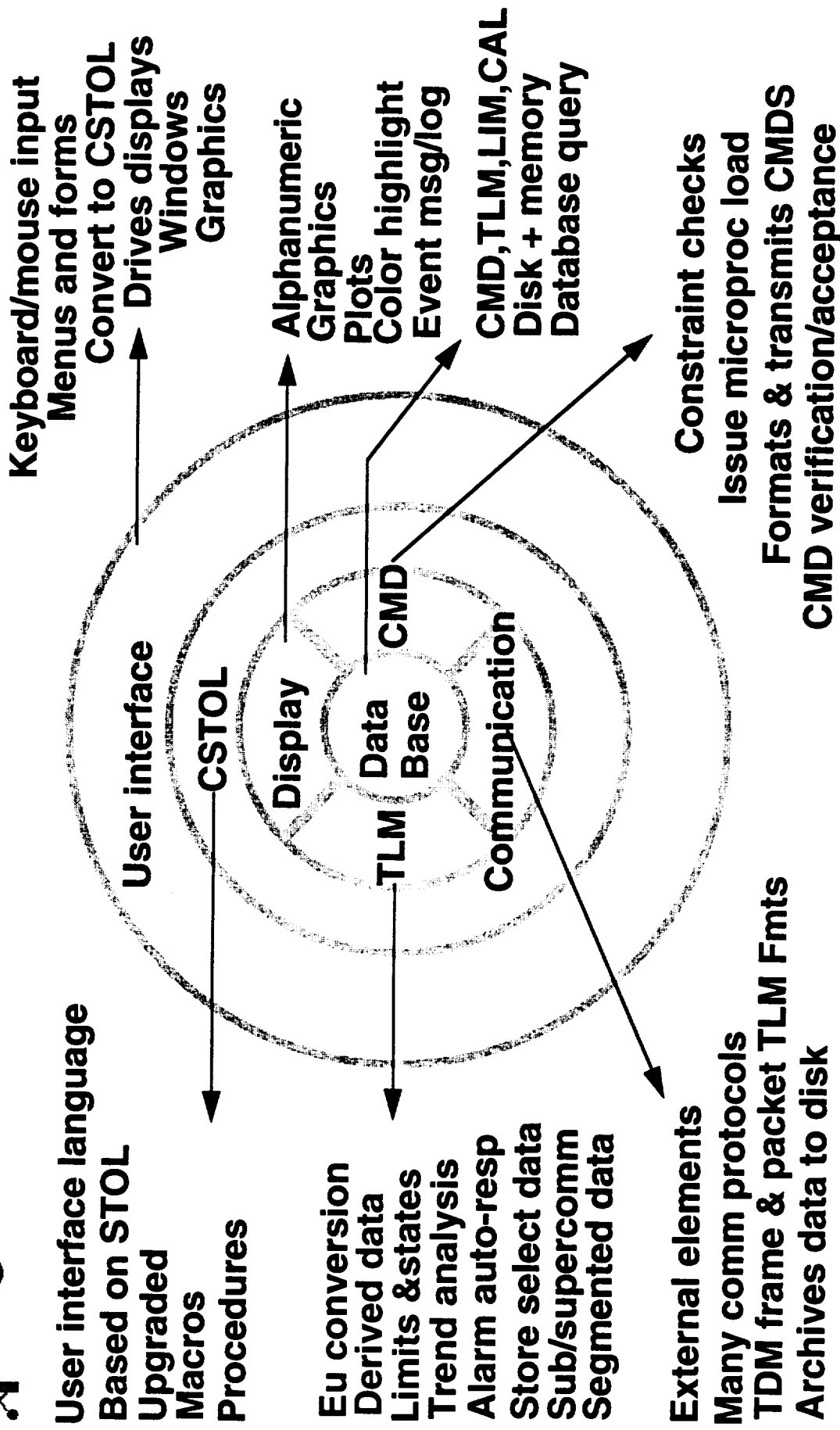


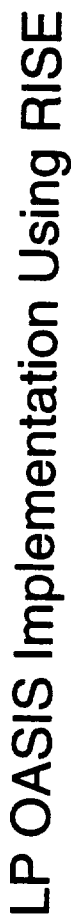


OASIS Functions & Features

— Integration and Test

LOCKHEED MARTIN

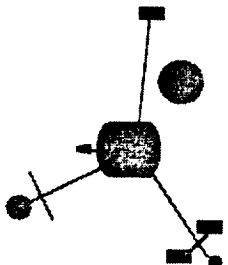




— Integration and Test

LOCKHEED MARTIN

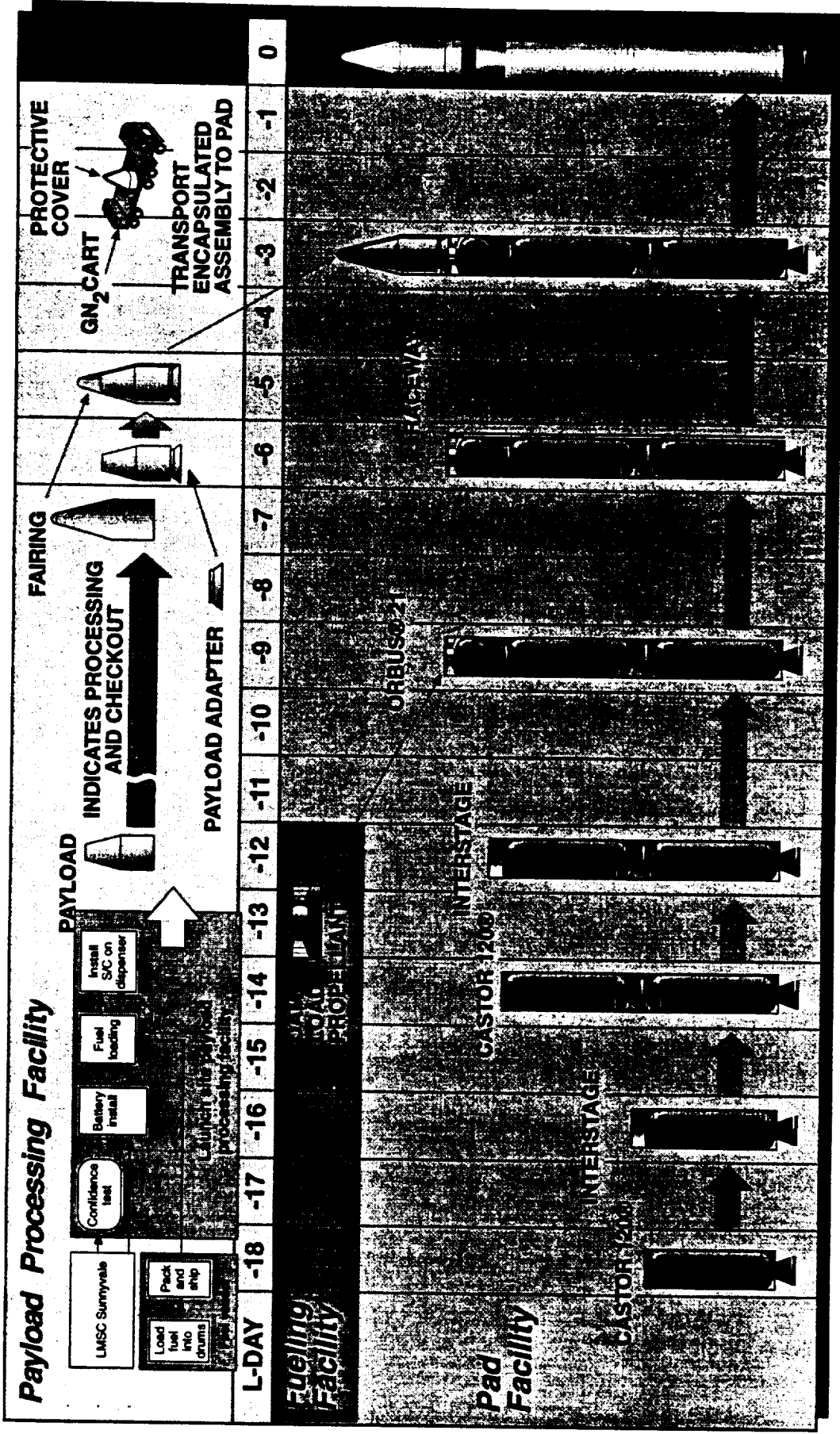




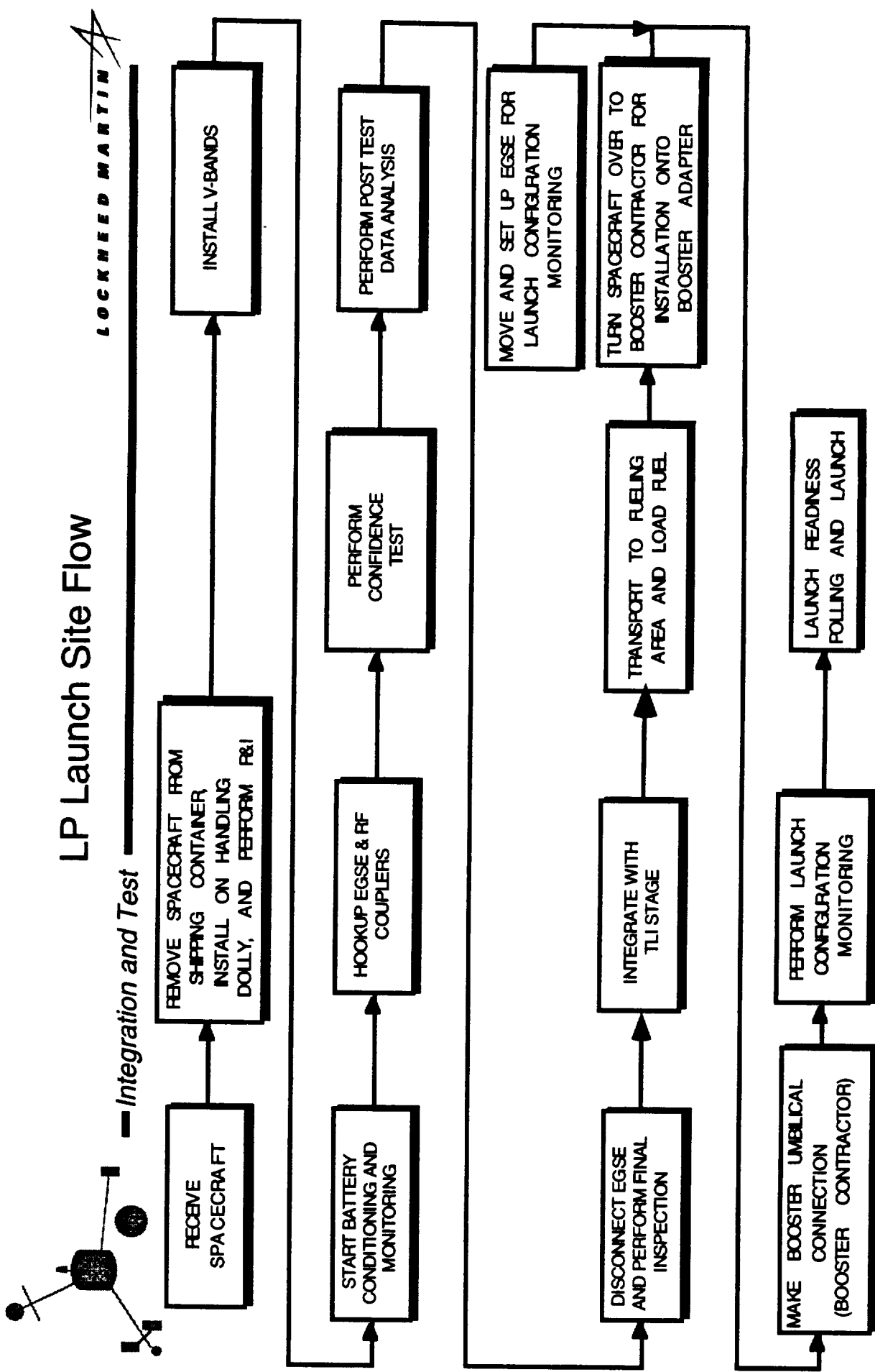
LP/LLV2 Ship and Shoot Approach

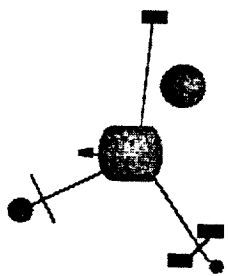
LOCKHEED MARTIN

Integration and Test



INDICATES PROCESSING AND CHECKOUT

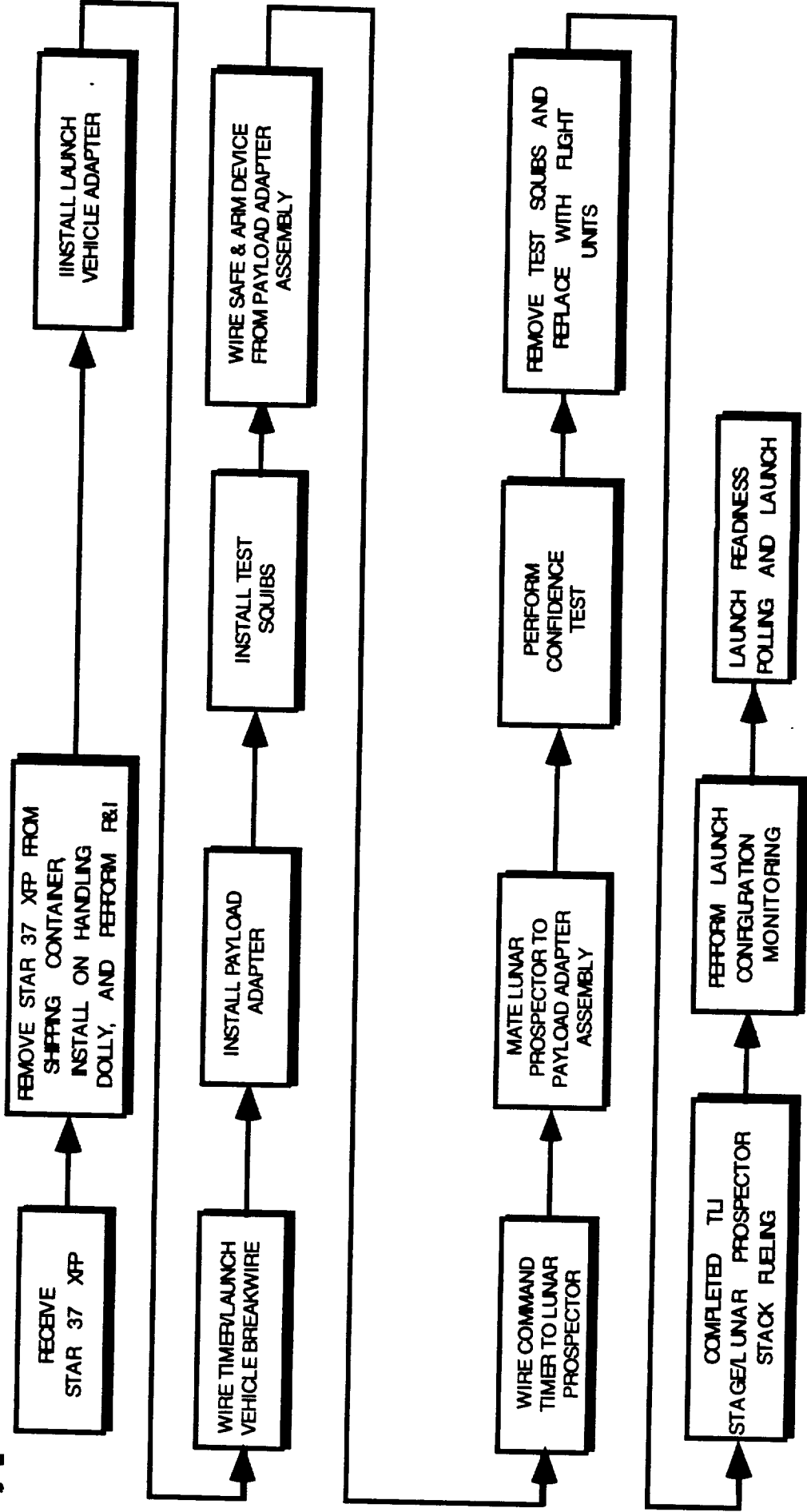




TLI Integration Flow

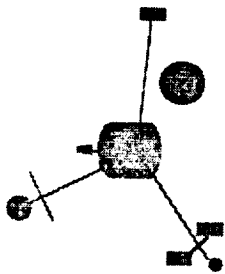
LOCKHEED MARTIN

Integration and Test



11.0 LAUNCH VEHICLE

R. LYNCH



Launch Vehicle

LOCKHEED MARTIN



Launch Vehicle

R. Lynch

Topics

Launch Vehicle

LOCKHEED MARTIN

- Functions
- Key Requirements
- System Description
- Hardware
- Test
- Schedule
- Issues



▪ Launch Vehicle

Requirements

LOCKHEED MARTIN



- Provide on pad interfaces (Trickle charge, cooling, etc.)
- Launch from Eastern Range on October 9, 1995
- Direct injection of Lunar Prospector spacecraft and Trans-Lunar Injection stage into the required park orbit

– Inclination	30.06°	±0.06°
– Longitude of Ascending Node	-2.551°	±0.25°
– Semi-Major Axis	6663.29 km	±5.4 km

Injection
Timeline
⇒ azimuth
variation

- Provide initial spin capability

- Separate Lunar Prospector/Trans-Lunar Injection Stage Stack from Launch Vehicle

⇒ instantaneous
launch
window

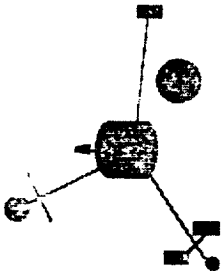
Launch Vehicle Options

Launch Vehicle

LOCKHEED MARTIN

	LLV2		Titan II		Commercial Taurus	
	Stage 1	Castor 120	Stage 1	Liquid	Stage 0	Castor 120
	Stage 2	Castor 120	Stage 2	Liquid	Stage 1	Orion 50s
	Stage 3	Orbus 21D	Stage 3	Star 37	Stage 2	Orion 50
	Stage 4	OAM	20' PLF		Stage 3	Orion 38
	Stage 5	Star 37			Stage 4	Star 37
	92" PLF				92" PLF	
Cost	22		20 - 30		20 - 30	
Fairing Dynamic Envelope						
Cylindrical	78.1" dia. x 90.2"		111.7" dia. x 144"		80.9" dia. x 94.05"	
Conical	35.8" dia. x 78.8"		78.9" dia. x 61.75"		57.5" dia. x 60.0"	
Performance						
ER (154 nmi, 30.0)	1470 kg		2000 kg		1460 kg	
ER (81 nmi, 30)	1670 kg		2200 kg		1660 kg	
Launch Site						
ER	LC-46		LC-40		LC-17, LC-46	
Spin Capability	3-5 rpm		3-5 rpm		60 rpm	
Injection Accuracy						
Semi-Major Axis	±5.4 km		±22.2 km		±25 km	
Inclination	±0.06°		±0.15		±0.2°	
Environments						
Loads (Axial/Lateral)	8 G/±2.5 G		10 G/±2.5 G		8.6 G/±3.0 G	
Acoustics	131.7 dB OASPL (92")		134.4 dB (120")		130.6 dB (92")	
Random Vibration (@P/L I/F)	0.06 G ² /1000Hz		0.07G ² /1400Hz		0.008G ² /1000Hz	
Shock (@P/L, I/F)	1500G @ 1500 Hz		200 G @ 1250 Hz		1076 G @ 1075 Hz	
Payload Processing	Encapsulation at Astrotech		Done at the Pad		Encapsulation at Astrotech	
Spacecraft Integration	Low		Med		High	
Flight history	0/0 *		3/3		1/1	
Next Flight	10/9/97		NA		9/30/96	

* Uses Major Elements of LLV1

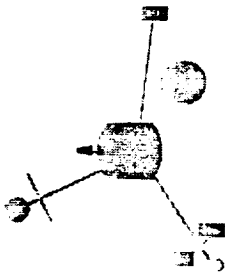


Launch Vehicle

Selection Criteria

LOCKHEED MARTIN

- Cost
- Performance Capability
- Injection Accuracy
- Spacecraft Integration
- Flight History



Launch Vehicle Performance

Launch Vehicle

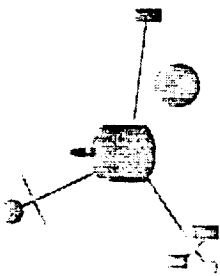
LOCKHEED MARTIN



- 285 km (154 nmi) circular orbit at 30.0° inclination
- Current Lunar Prospector Payload Requirement

	Mass (kg)	Mass (lb)
Lunar Prospector Wet Mass with contingency (281.75+22.95)	304.7	671.7
Payload adapter and separation system with contingency (24+6)	30.0	66.1
Spin rockets and brackets with contingency (4.2+1)	5.2	11.5
Launch Vehicle Adapter with contingency (16+4)	20.0	44.1
STAR 37 XFP Inert mass (includes Timer, Safe and Arm)	73.2	161.4
Injectable MassTotal	433.1	954.8
STAR 37 XFP Propellant Mass	872.6	1923.8
Launch Vehicle Separation System	12	
Payload Attach Fitting	115	253.5
Total Payload Requirement	1432.7	3132.1

LLV 2 performance margin of 37.3 kg
 Titan performance margin of 367.3 kg
 Taurus performance margin of 27.3 kg



Launch Vehicle

Performance

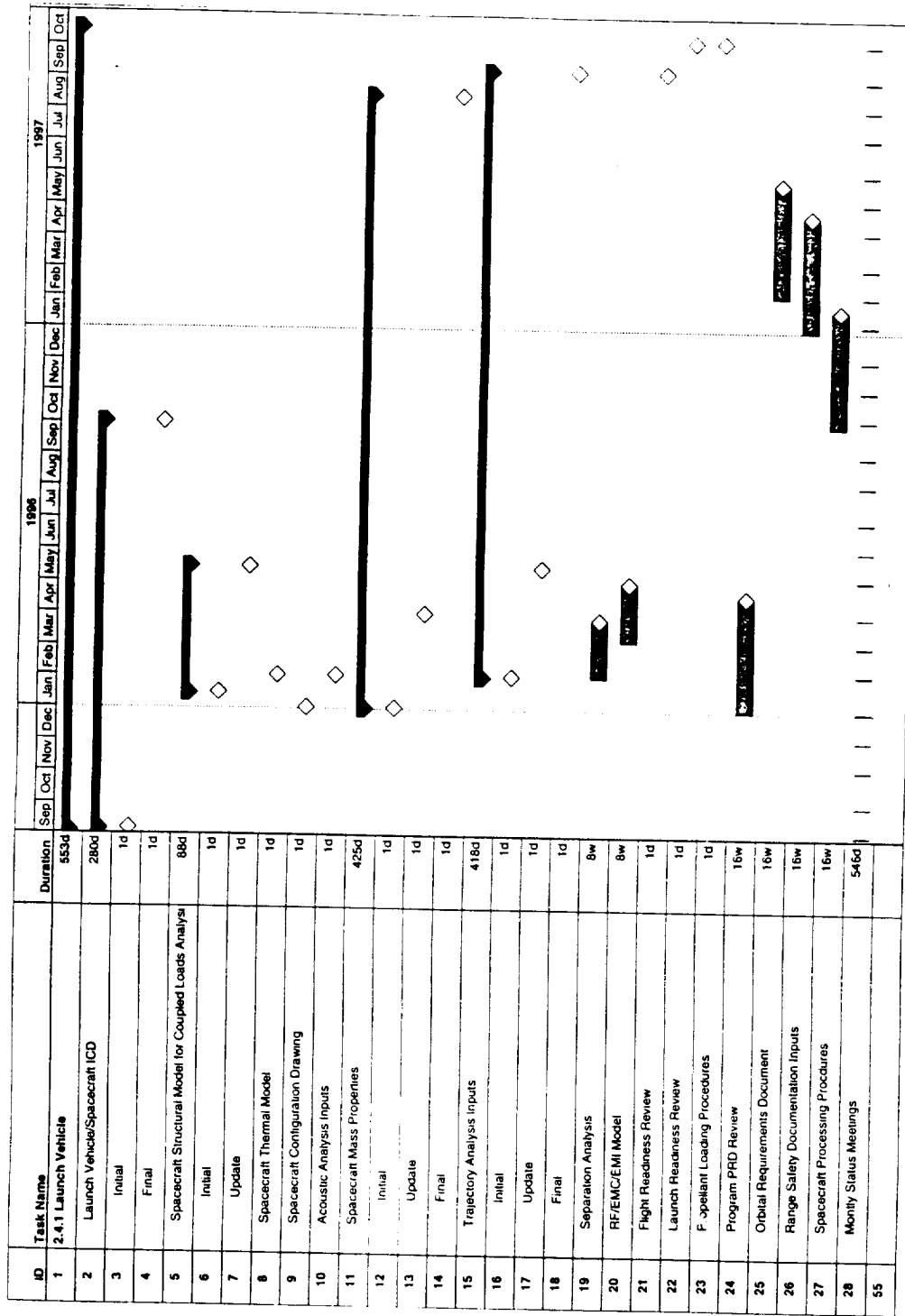
LOCKHEED MARTIN

- Current launch vehicle performance is for a specific trajectory assuming direct injection
- Direct injection for LLV2 results in an increase in the ΔV gravity loss for the OAM and reduce the excess performance
- STAR 37 FM can be used to increase excess performance by 95 kg

Schedule

Launch Vehicle

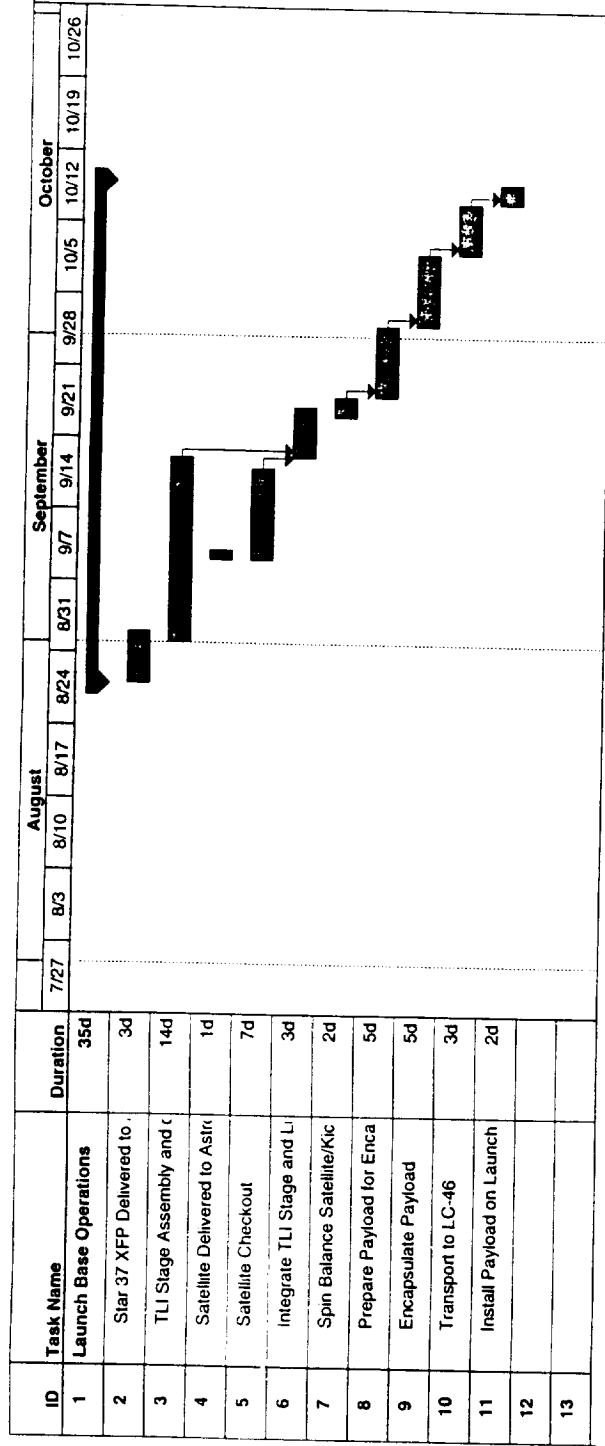
LOCKHEED MARTIN

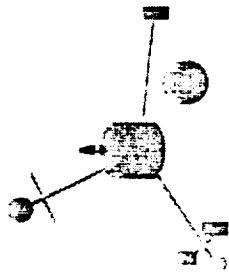


Schedule

Launch Vehicle

LOCKHEED MARTIN





Launch Vehicle Issues

Launch Vehicle

LOCKHEED MARTIN



- Selection of Launch Service Provider 12/15/95
- Excess Performance Margins 10/1/95
- Launch Pad at Eastern Range

Trans-Lunar Injection Stage

Richard Lynch

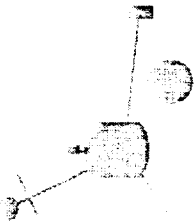
Function

TLI Stage

LOCKHEED MARTIN



- Provides ΔV to place Lunar Prospector on a Trans-Lunar trajectory
- Provides structural support for Lunar Prospector during the Ascent phase
- Provides "Power-on" signal to Lunar Prospector



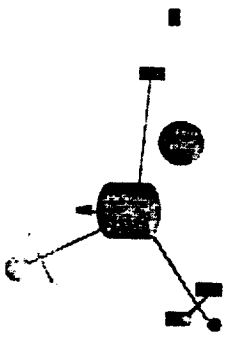
Requirements

TLI Stage

LOCKHEED MARTIN



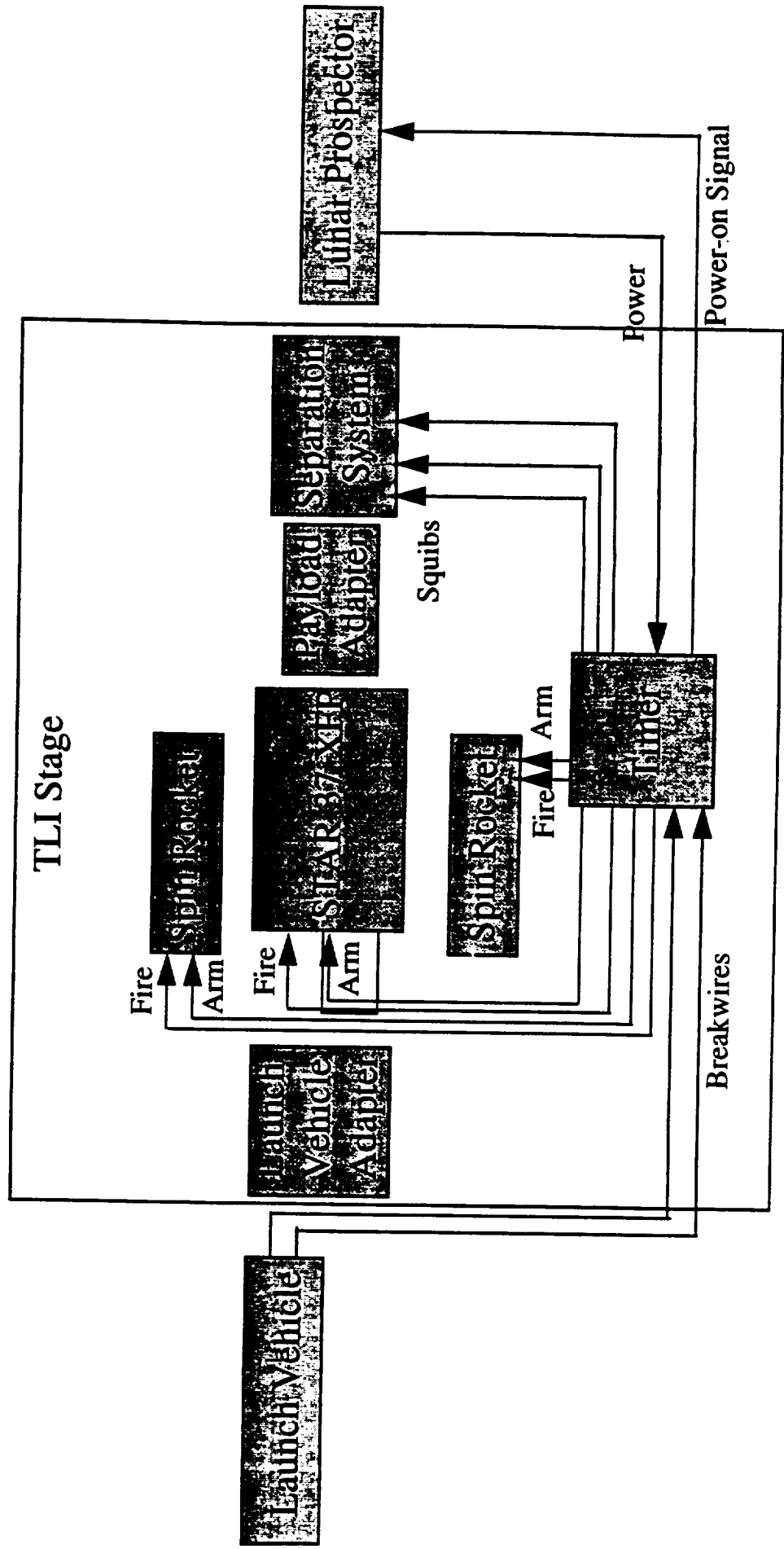
- Inject Lunar Prospector into a Lunar transfer trajectory
 - From a 285 km (154 nmi) circular parking orbit requires $\Delta V=3,107$ m/s
 - Utilize a timer to perform injection sequence of events after separation from the Launch Vehicle
 - Spin-up rockets ignition
 - STAR 37 XFP ignition
 - LP/TLI separation
- Minimize mid-course ΔV required to correct for injection errors
 - Maximum Isp uncertainty of 0.5%
 - Maximum TLI/LLV separation tip-off rates of 2.5 °/sec
 - Maximum TLI/LLV separation pointing error of 1.0°
 - Maximum coning angle of 5°
 - Spin rate while thrusting of 57 ± 3 rpm

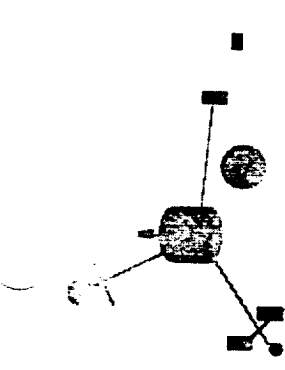


Interface Block Diagram

TLI Stage

LOCKHEED MARTIN

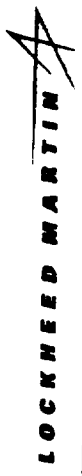




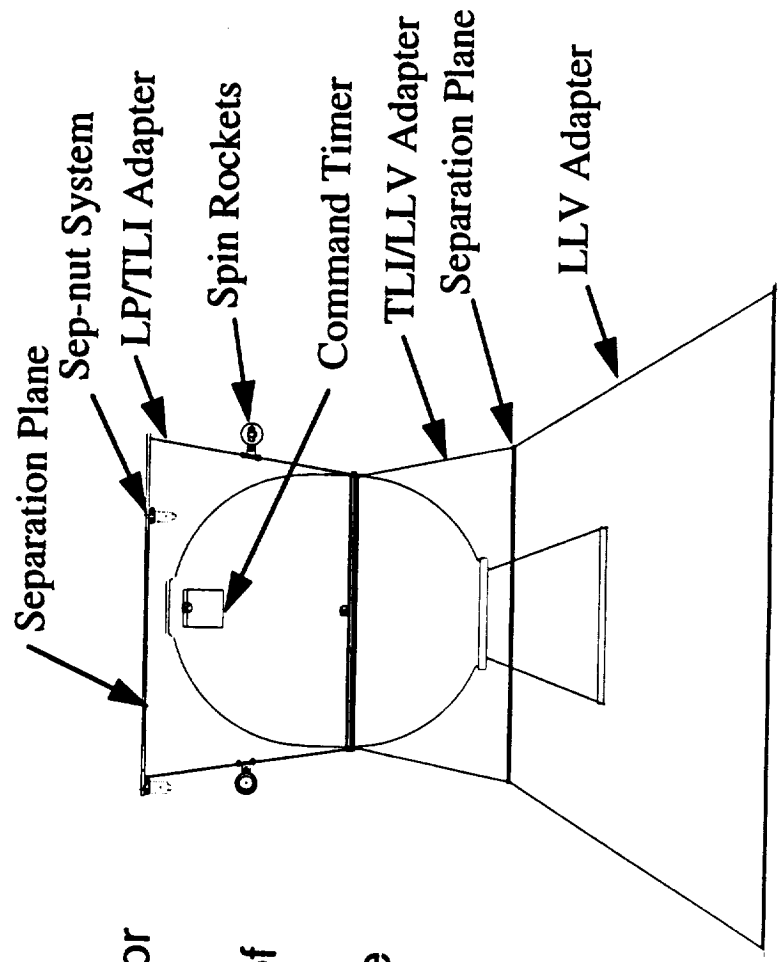
Trans-Lunar Injection (TLI) Stage

Configuration

TLI Stage



- STAR 37 XFP is the solid rocket motor for the TLI stage
- Two 1 lb spin-rockets (total impulse of 420 lbf-sec) are used to spin-up the TLI/LP stack after separation from the LLV 2
- Marmon Clamp Separation System used for TLI/LLV
- Sep-nut Separation System used for LP/TLI interfaces



PHSL

TLI Stage

LOCKHEED MARTIN

PROGRAM HARDWARE/SOFTWARE LIST (HARDWARE)			TITLE: Trans Lunar Injection Subsystem PROGRAM OFFICE APPROVAL:				Richard Lynch -66832		STATUS E=EXISTING N=NEW M=MODIFY		CATEGORY D=DEV Q=QUAL R=REL F=FLIGHT S=SPARES		SEC CLASS	
ITEM#	WBS #	NOMENCLATURE	DRAWING NO. /	SPEC NO.	STATUS		BUY	QUANTITY PER CONTRACT					SEC CLASS	
					DESIGN	HDW		D	Q	R	F	S		TOT
1	2.4.2.1	STAR 37 XFP Solid Rocket Motor Safe and Arm Device	P402L001	P402S001	E	E	S					1		1
2	2.4.2.2	STAR 37 to Launch Vehicle Adapter Ring Forging Transition Section Skin And Stringers	P402L020	P402S020	N	N	M					1		1
3	2.4.2.3	STAR 37 to Lunar Prospector Adapter Ring Forging Conical Section Thruster supports Fittings	P402L030	P402S030	N	N	M					1		1
4	2.4.2.4	STAR 37 XFP to Lunar Prospector Separation System	P402L040	P402S040	N	N	M					1		1
5	2.4.2.5	Solid Motor Spin Rockets	P402L050	P402S050	E	E	B					2		2
6	2.4.2.6	Command Timer	P402L060	P402S060	E	E	B					1		1

Equipment Characteristics

TLI Stage

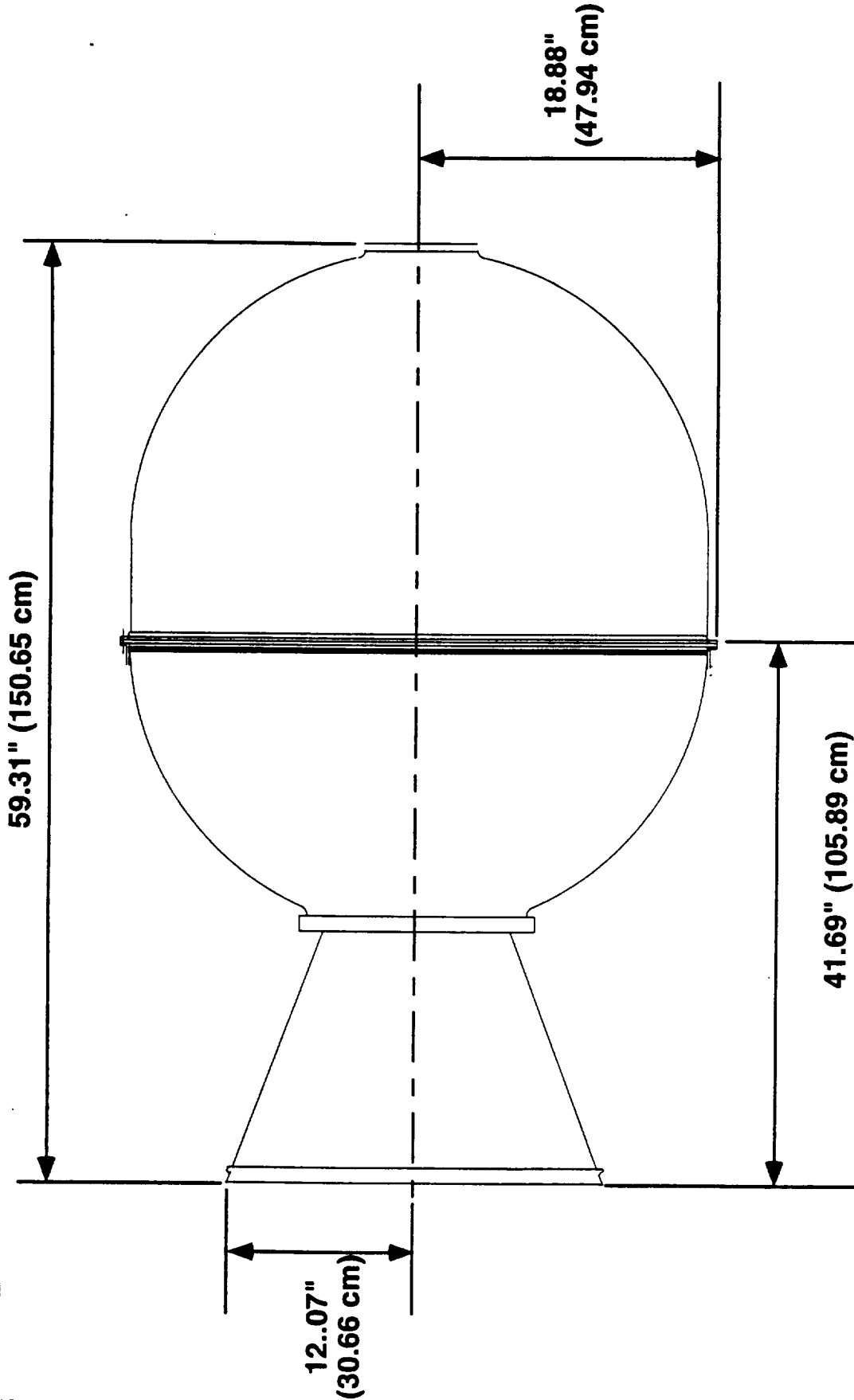
LOCKHEED MARTIN

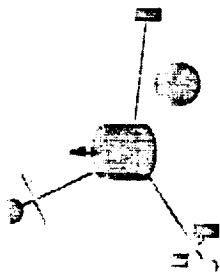
ITEM #	WBS #	Component	Source	Heritage	Quantity	Size (cm) (LxWXH) or (DxH)	Mass (kg)	Power (W)
1	2.4.2.1	STAR 37 XFP	THIKOL	XFP	1	95.9 x 150.6	945.80	NA
	2.4.2.1.1	SAFE & ARM DEVICE	THIKOL	2134B	1	15 x 15 x 15	1.60	1.0
2	2.4.2.2	LLV/TLI ADAPTER	LMMS	New	1	119.4 x 55.1	20.00	NA
3	2.4.2.3	TLI/LP ADAPTER	LMMS	New	1	63.5 x 63.5	27.00	NA
4	2.4.2.4	TLI/LP SEPARATION SYSTEM	TBD	CRSS	1	3 x 3	3.00	1.0
5	2.4.2.5	SPIN ROCKET	ATLR	Delta II	2	7.8 x 25.9	1.60	1.0
	2.4.2.5.1	SPIN ROCKET BRACKET	LMMS	N/A	2	AR	0.50	NA
6	2.4.2.6	EVENT TIMER	LMMS	New	1	12x12x7	1.00	2.0
Totals							1002.6	5.0

STAR 37 XFP

TLI Stage

LOCKHEED MARTIN





TLI Motor

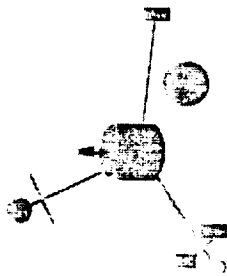
Launch Vehicle

LOCKHEED MARTIN



- TLI motor sized for an injectable mass of 433.1 kg
- For a ΔV of 3,137.9 m/s the STAR 37 XFP has an excess performance margin of 5.0 kg of payload (10.5 kg propellant)

Injectable Mass (kg, lb)	433.1	954.8
ΔV Insertion (m/s, ft/s)		
ΔV Losses (m/s, ft/s)	3106.8	10192.9
Total ΔV (m/s, ft/s)	31.1	101.9
	3137.9	10294.8
STAR 37 XFP Effective Isp (lbf-sec/lbm)		289.95
STAR 37 XFP Maximum Propellant Mass (kg, lb)	883.1	1947.0
Propellant Mass (kg, lb)	872.6	1923.8
Excess Propellant (kg, lb)	10.5	23.2



TLI Motor

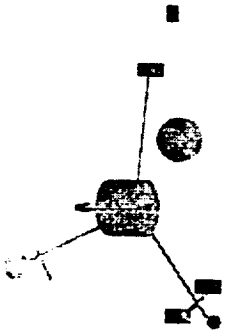
Launch Vehicle

LOCKHEED MARTIN



- For a ΔV of 3,137.9 m/s the STAR 37 FM has an excess performance margin of 95.0 kg of payload (169.9 kg propellant)

Injectable Mass (kg, lb)	433.1	954.8
ΔV Insertion (m/s, ft/s)		
ΔV Losses (m/s, ft/s)	3106.8	10192.9
Total ΔV (m/s, ft/s)	31.1	101.9
	3137.9	10294.8
STAR 37 FM Effective Isp, nominal 70°F (lbf-sec/lbm)		289.83
STAR 37 FM Maximum Propellant Mass (kg,lb)	1065.7	2349.5
Propellant Mass (kg, lb)	872.6	1923.8
Excess Propellant (kg, lb)	193.1	425.7



STAR 37 XFP Heritage

TLI Stage

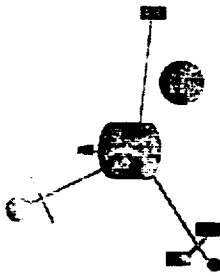
LOCKHEED MARTIN



- Design similarity to other STAR 30, STAR 37, and STAR 48 motors
- Materials same as materials used in other STAR motors
- Demonstrated 99.85% success rate over 35 years (all STAR motors)

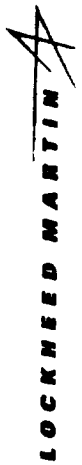
Tests	
Other STAR 37 (1961 - 1978)	96
STAR 37S (1973 and 1986)	2
STAR 37XFP (1980 - 1989)	12
STAR 37FM (1983 - 1986)	4
STAR 37V (1995)	1
Total	115

Flights			
	Opportunities	Successes	Failures
Other STAR 37 (1966 - 1987)	156	148	8
STAR 37S (1976 - 1994)	21	20	1
STAR 37XF/XFP (1983 - 1994)	37	36	1
STAR 37FM (1986 - 1994)	4	4	
Total	218	208	1



STAR 37 XFP Performance

TLI Stage



● STAR 37 XFP Predicted Performance at 55°F

Propellant grain weigh, nominal, lbm	1947
Ignition pressure, psia	478
Maximum pressure, psia	576
Average pressure, psia	527
MEOP (+3σ at 100°F), psia	639
Burn Time, sec	66.0
Action Time, sec	67.0
Ignition thrust, lbf	7,085
Maximum thrust, lbf	9,550
Average thrust, lbf	8,550
Total Impulse, lbf-sec	570,540
Propellant specific impulse, lbf-sec/lbm	292.57
Effective specific impulse, lbf-sec/lbm	289.95

● Performance Variability (3σ)

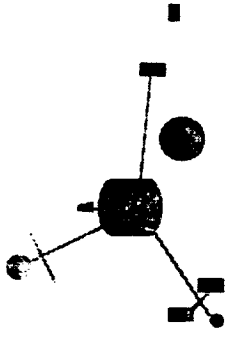
- Time, pressure, thrust ±6%
- Specific impulse ±0.45%
- Propellant weight variability ±3.5 lbm
- Temperature variability ±5°F

Mass Properties

TLI Stage

LOCKHEED MARTIN

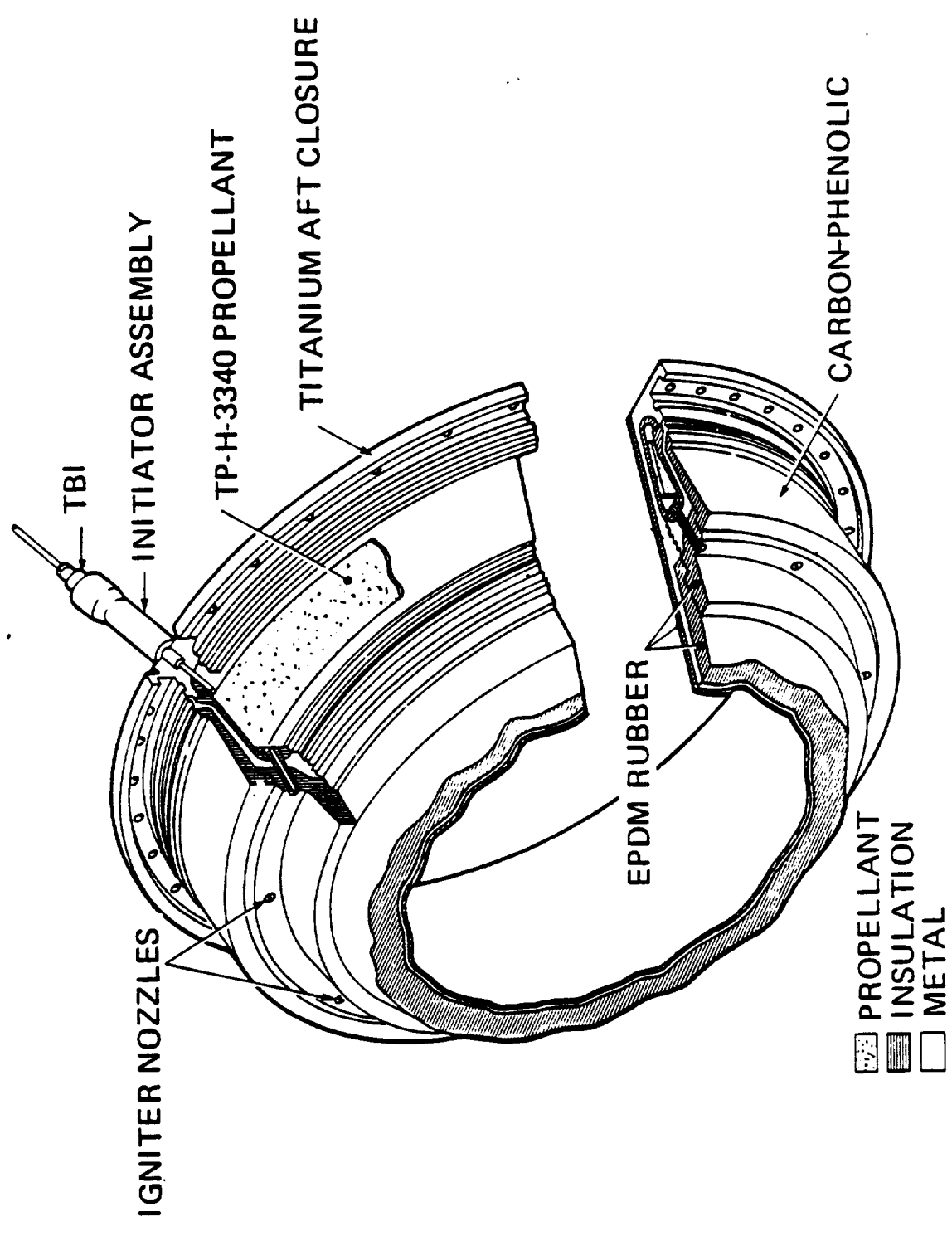
Item	Weight (lbm)	X (in)	Y (in)	Z (in)	I _{ox} (lbm-in. ²)	I _{oy} (lbm-in. ²)	I _{oz} (lbm-in. ²)
Case	59.3	0	0	-4.36	16101.1	16101.1	15175.5
Head-end plug	0.34	0	0	17.14	0.2	0.2	0.3
Insulation, case	26.8	0	0	-12.49	5980.5	5980.5	6448.5
Liner	1.16	0	0	-2.82	306.3	306.3	296.1
Propellant grain	1947	0	0	-3.14	319003.9	319003.9	294184.9
Igniter propellant	1.2	0	0	-23.34	30.4	30.4	60.1
Nozzle assembly	71.18	0	0	-23.09	4541.7	4541.7	3681.5
Initiator assembly and TBI (2)	1.17	0	0	-29.14	61.3	61.3	115.5
Hardware, nozzle installation	1.65	0	0	-25.14	62.4	62.4	124.8
RETA and installation items	0.92	4.57	4.57	-25.47	42	42	58.1
Loaded motor	2110.72	0	0	-4.01	377988	377988	320183
Propellant grain	-1947	0	0	-3.14	-319003.9	-319003.9	-294184.9
Igniter propellant	-1.2	0	0	-23.34	-30.4	-30.4	-60.1
Inert weight expended	-17.64	0	0	-19.49	-2871.9	-2871.9	-2855.2
Fired motor	144.88	0.03	0.03	-13.73	36230	36230	23083
NOTES: S&A device and flexible ETA lines not included in these calculations Components expended after ignition are indicated by a minus sign							

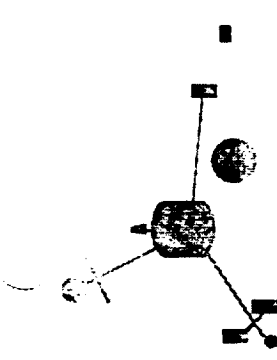


TLI Stage

Toroidal Igniter

LOCKHEED MARTIN





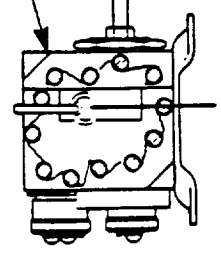
TL1 Stage

Typical Ignition Train

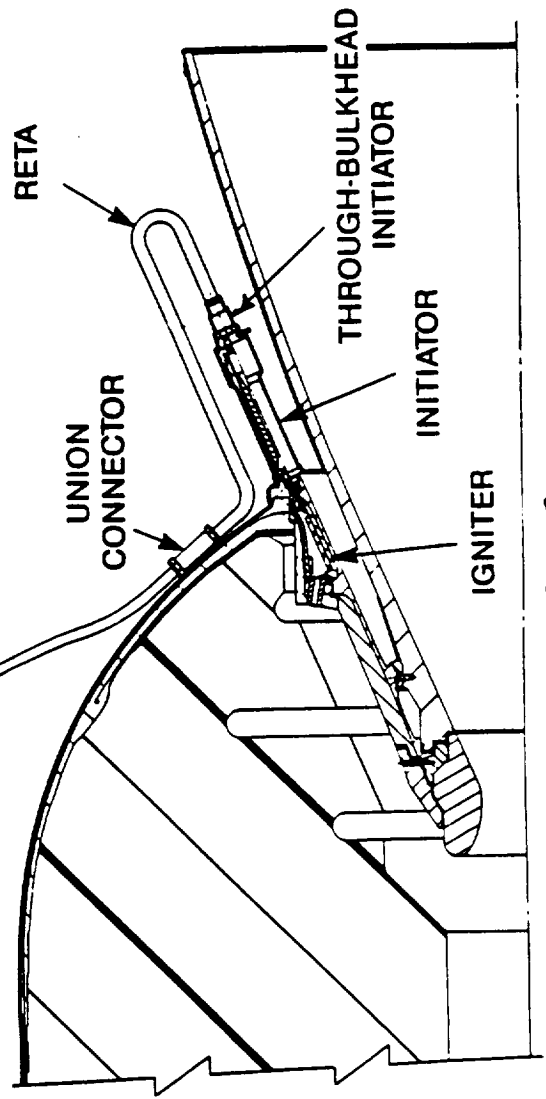
LOCKHEED MARTIN

8A27001A

SAFE-AND-ARM
DEVICE

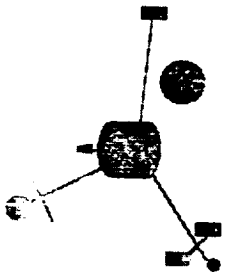


FETA



Model 2134B Safe-and-Arm Device	
Unit weight, lb	3.4 (typical)
Motor operating voltage, Vdc	24 to 32
Inrush, amps	1.0 to 3.0 for 50 ms max
Running, mA	100 to 250 at 28 ±4 Vdc
Stalled rotor current, mA	360 max
Actuation time, sec	0.15 to 0.3 at 28 ±4 Vdc
Operating temperature, °F	-35 to 160
Firing circuit pin-to-pin resistance, ohms	0.87 to 1.07
Detonator "no-fire" current/power	1 amp/1 watt for 5 minutes
Detonator "all-fire" current, amps	3.5
Detonator recommended firing current, amps	5.0 to 22.0
Firing time at 5.0 amps, ms	3 (typical)

Thiokol CORPORATION, Elkton Division

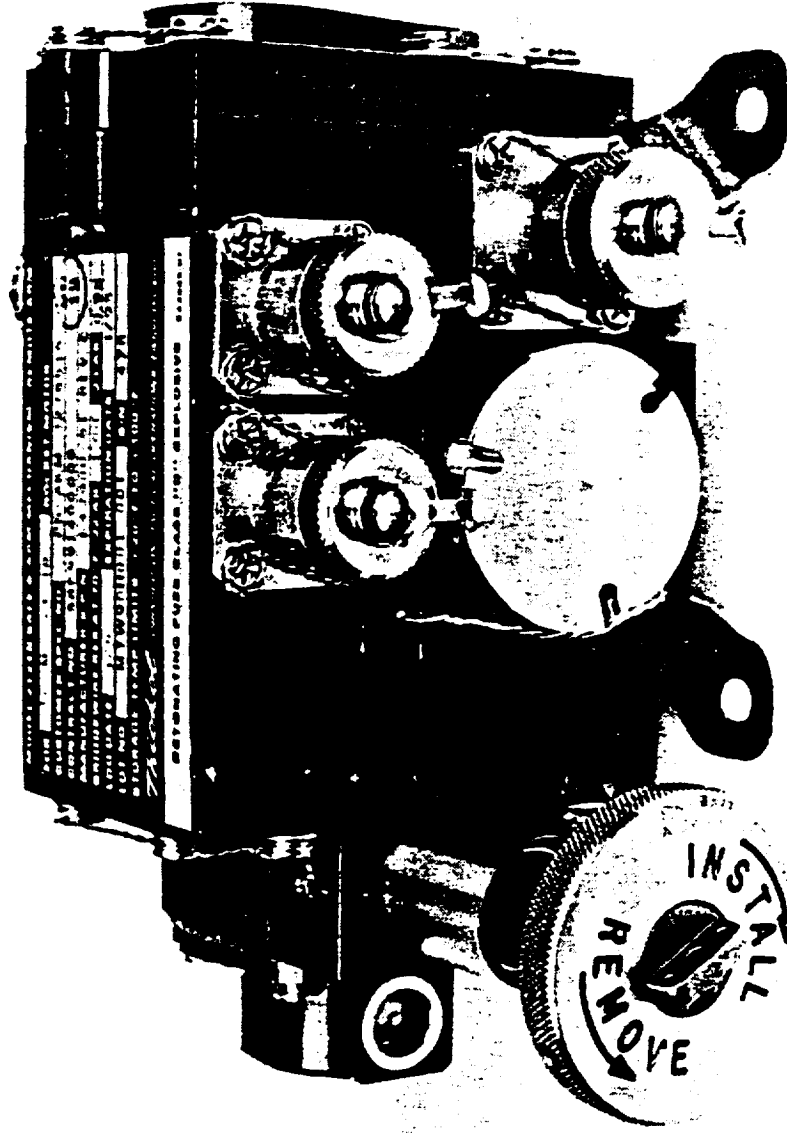


Safe and Arm Device

TLI Stage

LOCKHEED MARTIN

MODEL 2134B S&A (WITHOUT ISOLATORS)



Thiokol CORPORATION, Elkon Division

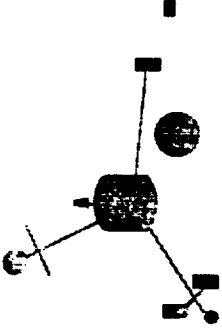
S&A Flight History

TLI Stage

LOCKHEED MARTIN



- 206 S&A devices flown to date (60 model 2134A and 146 model 2134B)
 - 116 for solid rocket motor ignition
 - 90 for destruct applications
- Model 2134B flown on Ariane, Aries, Atlas I, Orbus, Atlas/Centaur, Delta II, Joust, MAXUS, Long March 2E, and Taurus
- Model 2134A flown on STS-28 and -30, Titan IIIC, H-1



TL/I Stage

S&A Safety

LOCKHEED MARTIN



- Safe if inadvertently fired in safe position
- Remote arm/disarm capability
- Manual disarm capability - no manual arm capability
- Separate, noncompatible firing and control/monitor connectors
- Visual Safe/Arm indicator
- Safety pin nonremovable when arming power applied
- Detonator lead wires shunted in safe position
- 1-amp/1-watt detonator that complies with MIL-STD-1576 and NHB 1700.7A ESD requirement

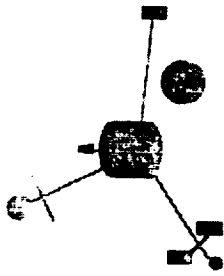
Launch Vehicle Adapter and

Separation System Requirements

TLI Stage

LOCKHEED MARTIN

- Separate the Launch Vehicle from the Lunar Prospector/TLI stage stack with a relative ΔV of greater than 1 ft/s
- Pointing error at separation shall be less than 1.0°
- Separation tip-off rates shall be less than 2.5°/s
- Provide a separation breakwire monitor loop to the TLI stage command timer
- Not-to-exceed control weights
 - LP Launch Vehicle Adapter 20 kg
 - Separation System 12 kg
 - Launch Vehicle Payload attach fitting 115 kg

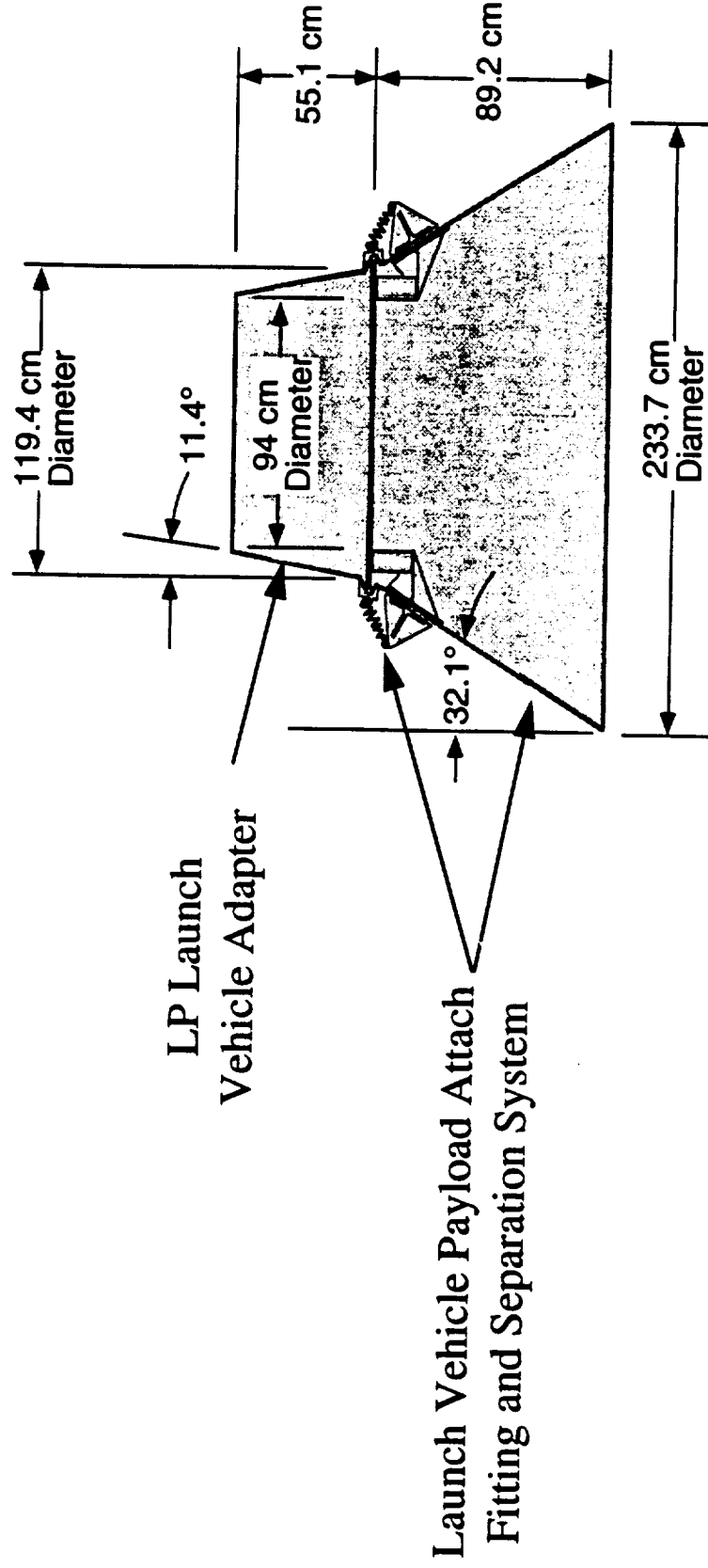


Launch Vehicle Adapter

TLI Stage

LOCKHEED MARTIN

- Lunar Prospector is responsible for the Launch Vehicle Adapter
- Lockheed Launch Vehicles provides the Payload Attach Fitting and Separation System

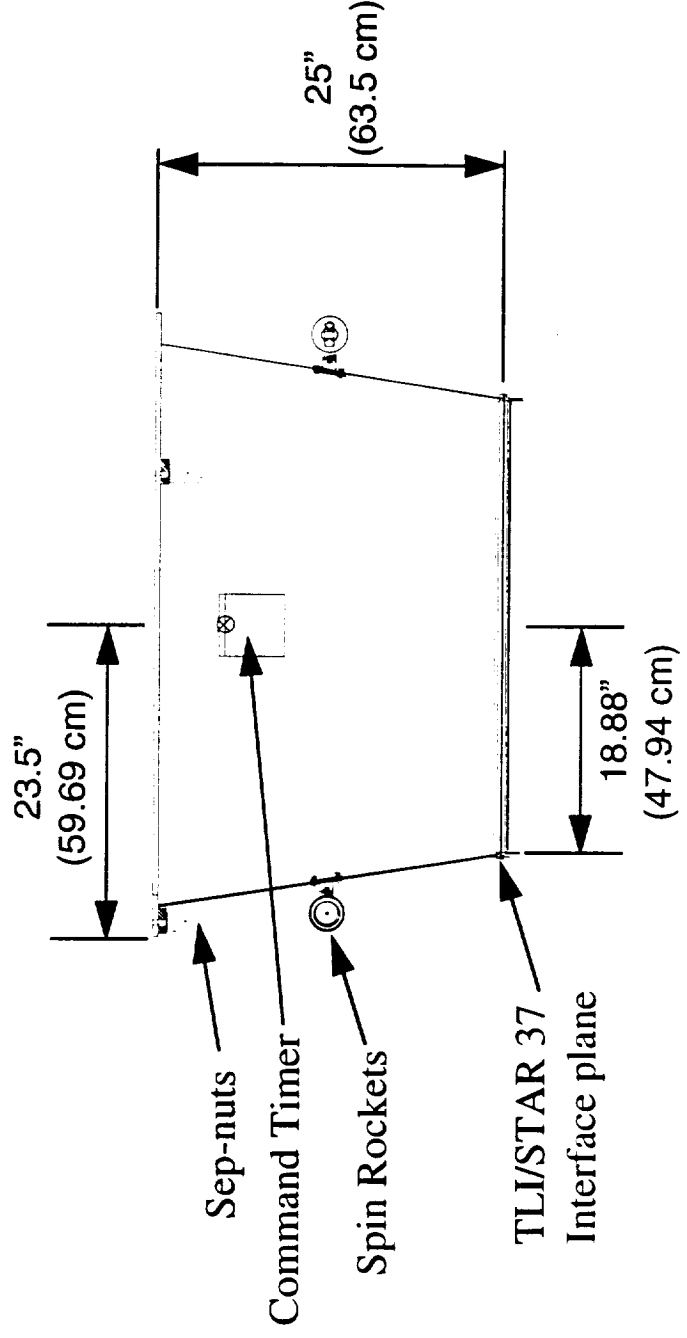
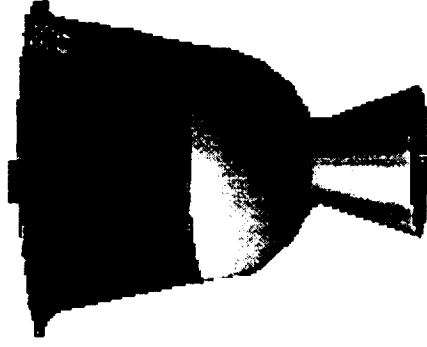


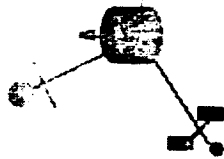
Payload Adapter

TLI Stage

LOCKHEED MARTIN

- Provides support for Lunar Prospector
- Provides mounting surface for command timer, and spin rockets
- Utilizes a sep-nut separation system





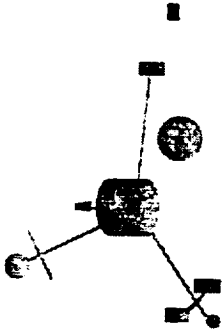
LP/TLI Separation System Requirements

TLI Stage

LOCKHEED MARTIN



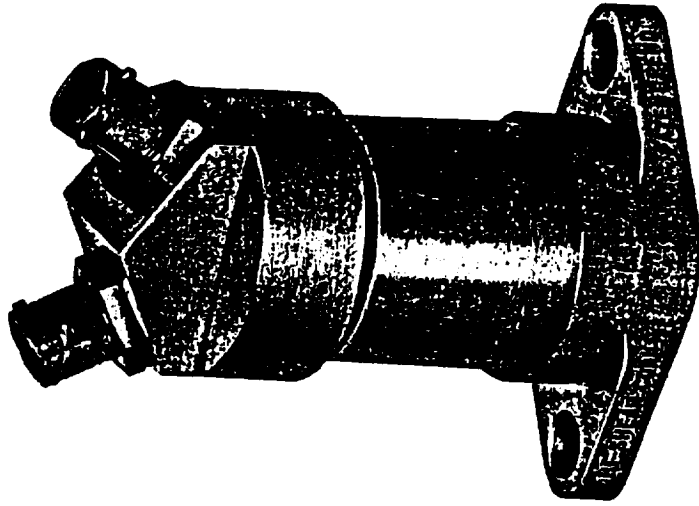
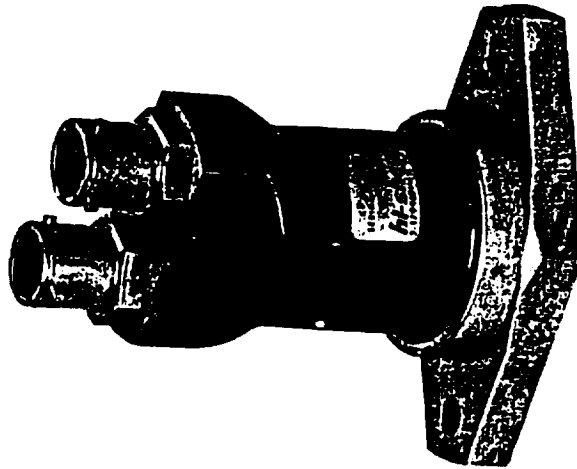
- Mass:
 - Separation System <10 kg
 - Above Separation System 260.8 kg
 - Below Separation System @ SEP 142.9 kg
- ΔV Relative: 0.305m/s
- Spin Rate at Separation: 60 rpm
- Tip-Off Rates (Pitch, Yaw) @ SEP ≤ 3.0 °/sec
- Max. Load:
 - Axial 10 g's
 - Lateral 2 g's



LP/TLI Separation System

TLI Stage

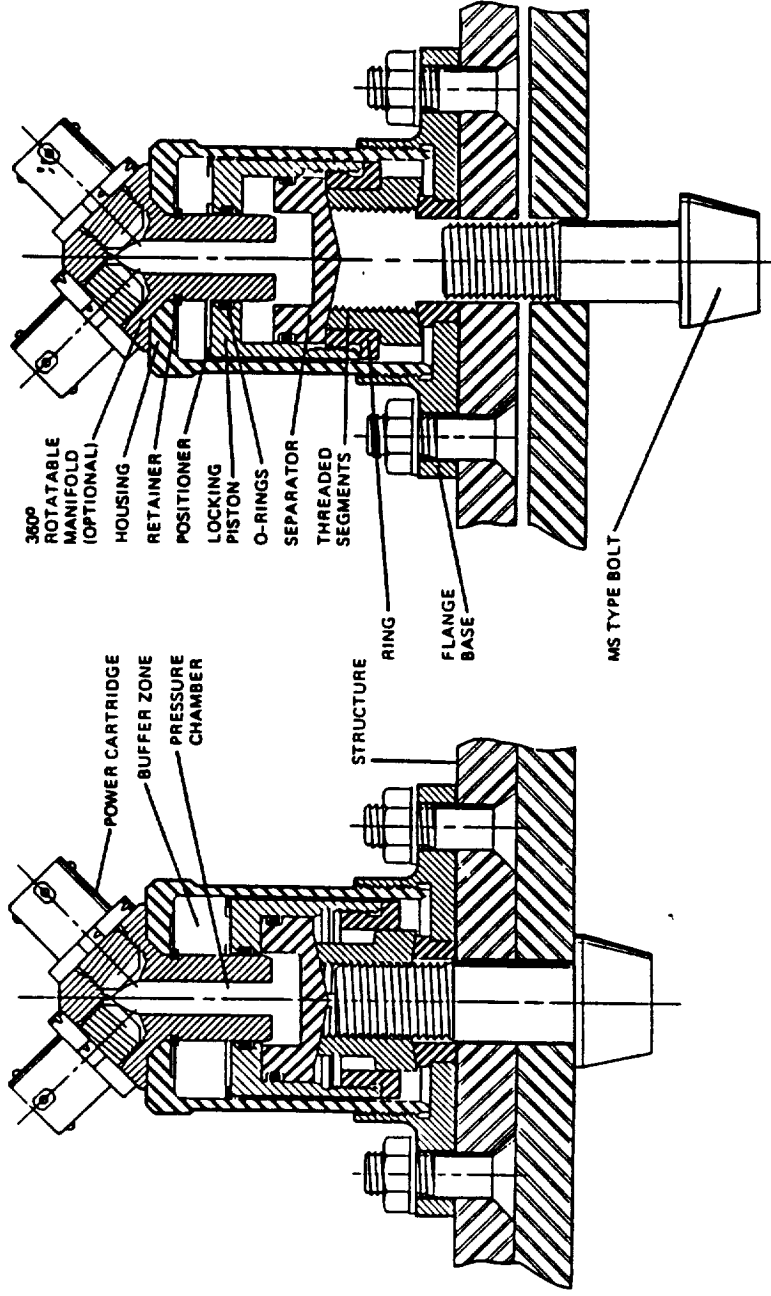
LOCKHEED MARTIN



Separation Nut Operation

TLI Stage

LOCKHEED MARTIN

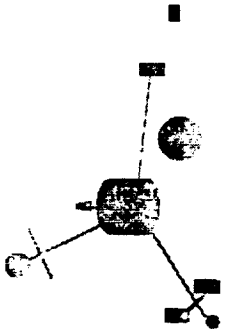


BEFORE ACTUATION

1. Bolt is threaded fully into nut segments.
2. Nut segments are fully supported by locking piston.
3. Structure joint is clamped up to tension rating of bolt.

AFTER ACTUATION

1. Gas pressure acts on locking piston, moving it away from bolt to unlock threaded segments.
2. Segments displace radially away from bolt.
3. Bolt ejects and structure joint separates.



Spin Rockets Requirements

TL1 Stage

LOCKHEED MARTIN

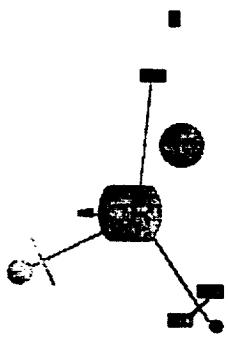
- Total Impulse 420 lbf-sec
- Burn time less than 2 seconds

Spin Rocket Performance

TLI Stage

LOCKHEED MARTIN

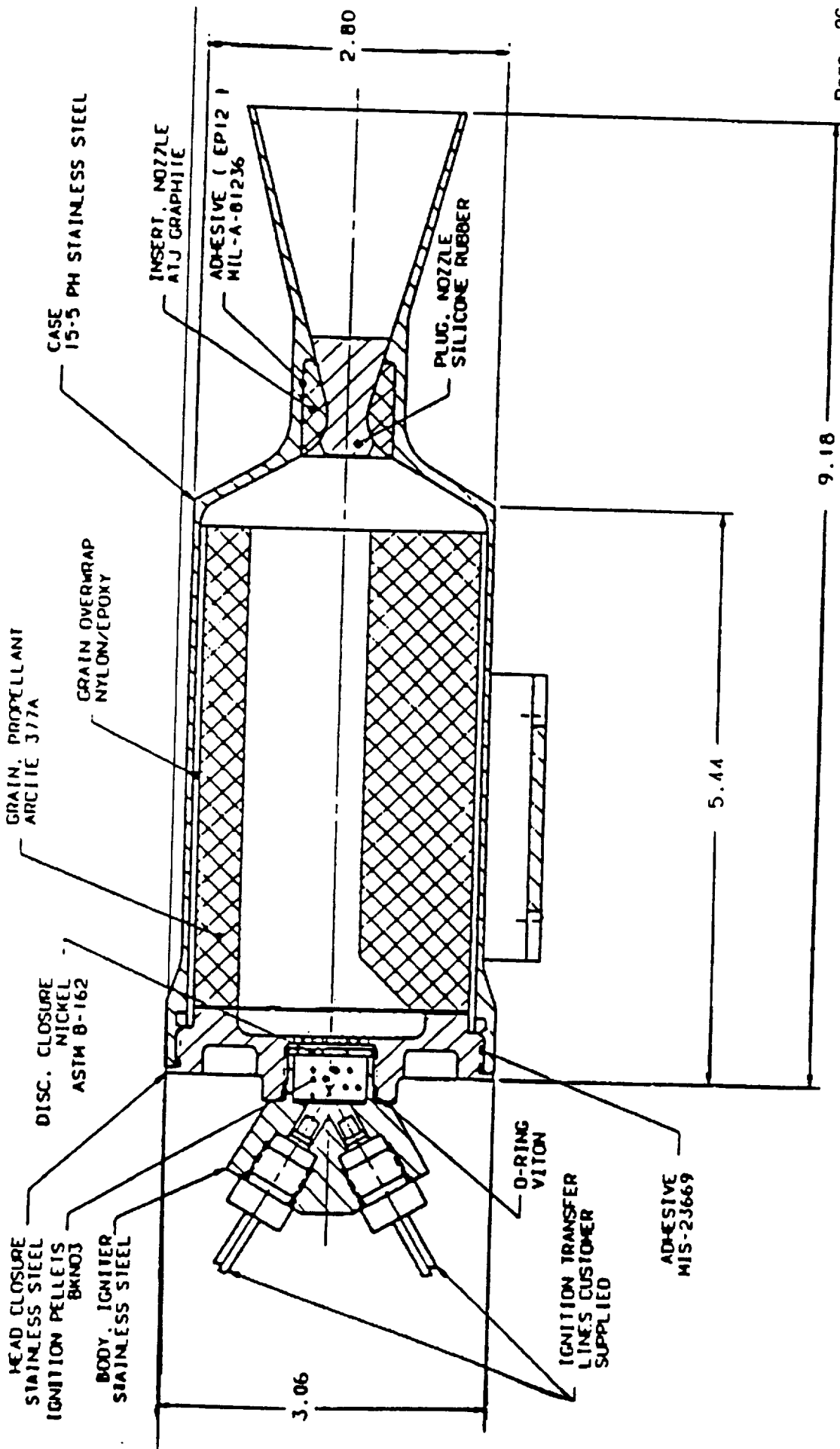
	-40°F	70°F	200°F
Total Impulse (Vacuum, lb-s)	250	259	268
Burning time (sec)	1.464	1.077	0.764
Action Time (sec)	1.839	1.501	1.237
Thrust (Vacuum, lbf)	155	214	308
Maximum Thrust (lbf)	164	221	309
Average Pressure (psi)	799	1046	1290
Maximum Pressure (psi)	848	1123	1397
Ignition Delay (msec)	<10	<10	<10
Specific Impulse delivered (Isp lbf-sec/lbm)	217	218	219
Thrust Coefficient	1.67	1.74	1.99



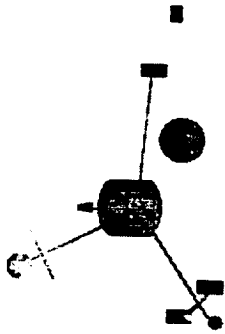
Spin Rocket Configuration

TLI Stage

LOCKHEED MARTIN



MOTOR ASSEMBLY 1.0-KS-210



Command Timer Requirements

TLI Stage

LOCKHEED MARTIN



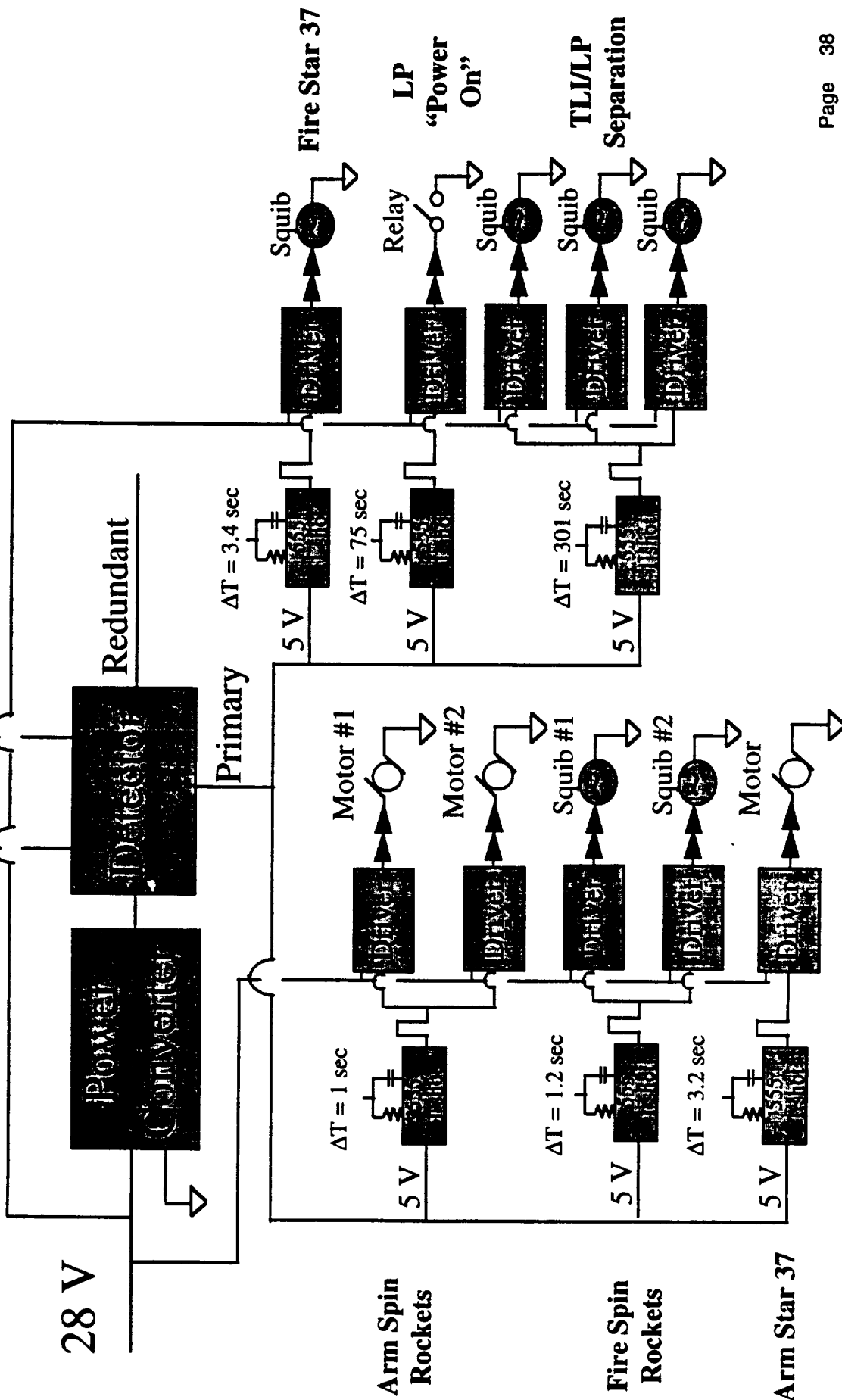
- Receive signal from LLV/TLI Separation Breakwire
- Provide 6 commands
 - Spin Rocket Arm
 - Spin Rocket Fire
 - Star 37 XFP Arm
 - Star 37 XFP Fire
 - LP Power-on
 - LP/TLI Separation
- Distribute 28 Vdc to TLI components

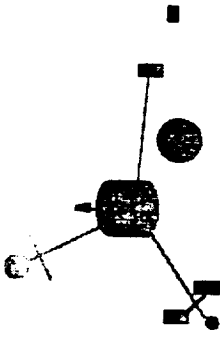
Timer Block Diagram

TLI Stage

LOCKHEED MARTIN

Breakwire





Manufacturing/Subcontracts

TLI Stage

LOCKHEED MARTIN



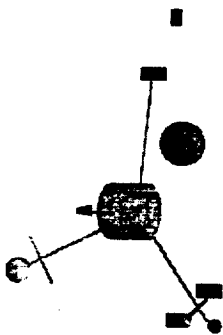
- Launch Vehicle statement of work and requirements document completed, awaiting authority to proceed
- Star 37 statement of work and specification completed, awaiting authority to proceed
- LP/TLI Separation System statement of work and specification completed, awaiting authority to proceed
- Spin rockets statement of work and specification completed, awaiting authority to proceed

Test Program/Verification

Launch Vehicle

LOCKHEED MARTIN





TLI Stage

TLI Issues in Work

LOCKHEED MARTIN

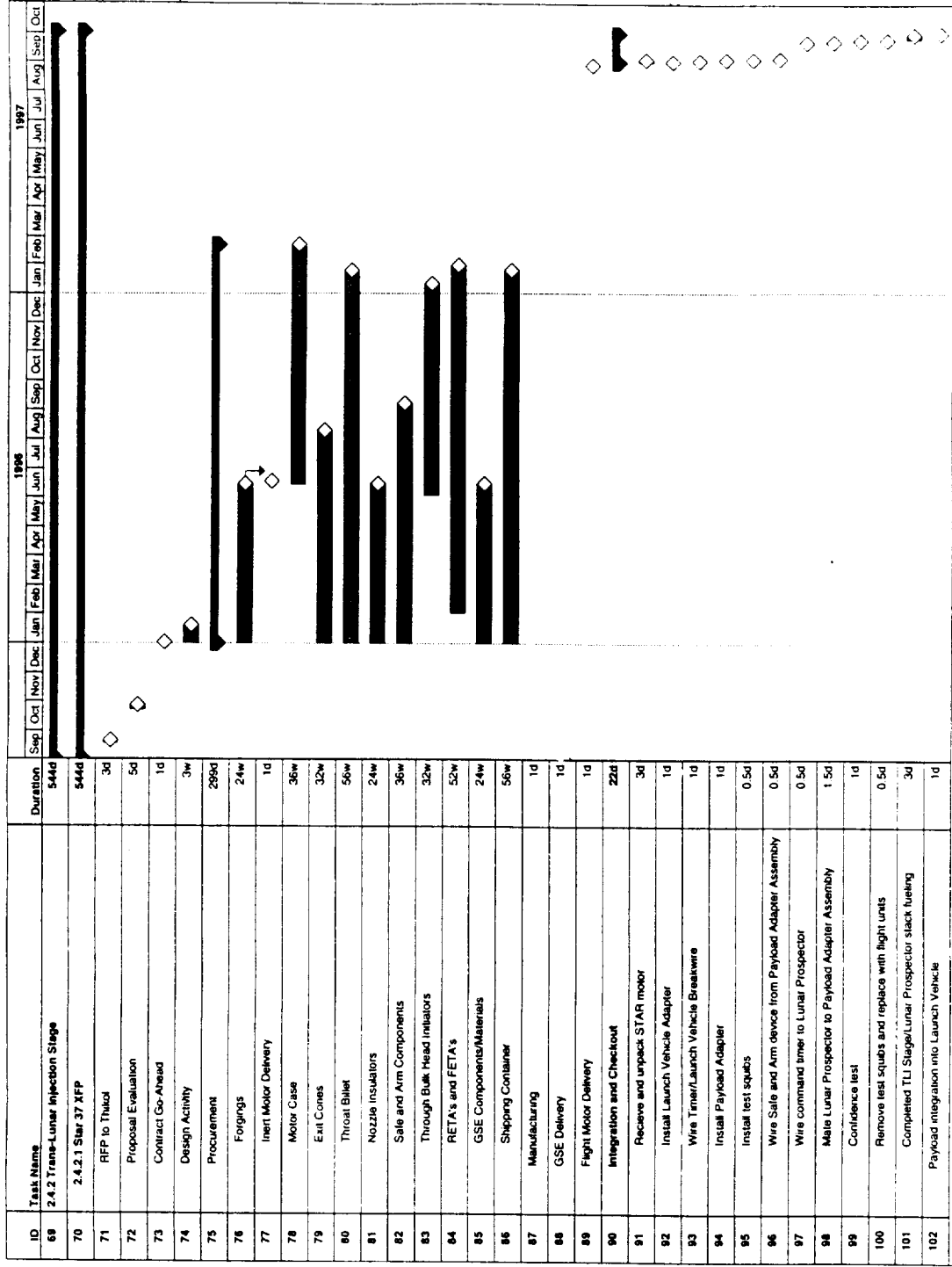


- Spin Rockets need to be ordered by 11/1/95 to take advantage of cost reductions due to the current production run

Schedule

LOCKHEED MARTIN

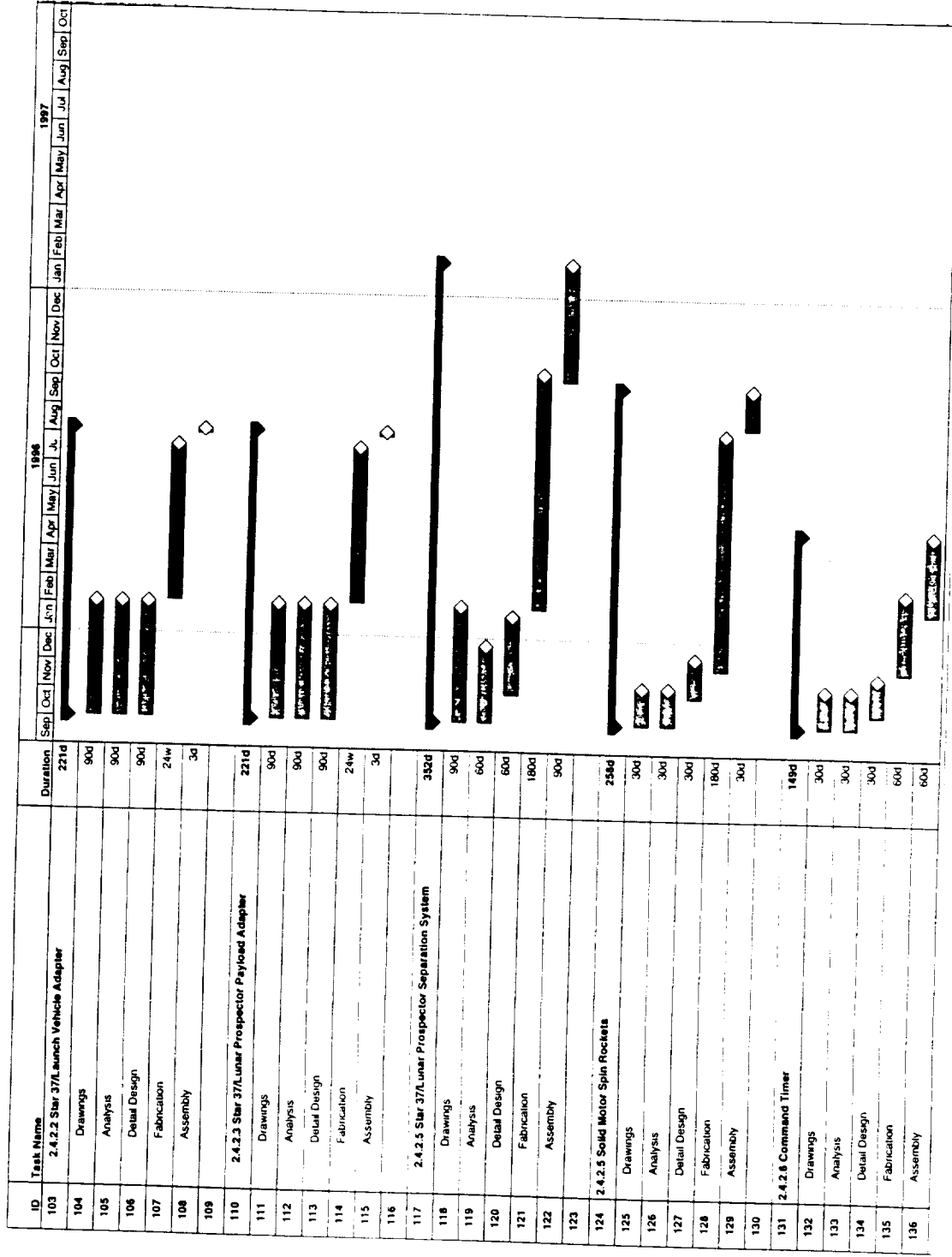
TLI Stage



Schedule

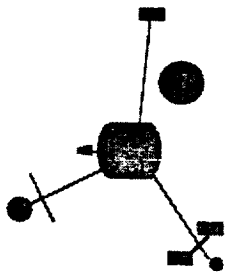
TLI Stage

LOCKHEED MARTIN



12.0 GROUND SYSTEM

**T. BRIDGES/
M. STEWART**



Ground System

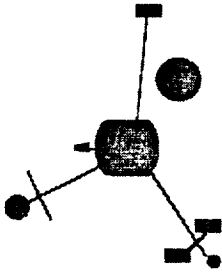
LOCKHEED MARTIN



Ground System

Tim Bridges

Page 1
Tim Bridges 9/6/95



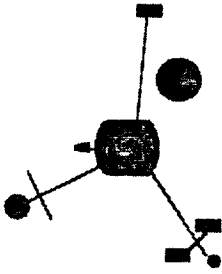
Tracking Requirements

— Ground System

LOCKHEED MARTIN



- Tracking Categories
 - Category 1: 2-way doppler @ 1 mm/sec, or better, over 10 sec period
 - Category 2: 2-way doppler @ 5 mm/sec, or better, over 10 sec period
 - Category 3: downlink only (no 2-way doppler) (Outreach Program)
- Availability - Minimum
 - Cat 1: Full coverage (24 hrs per day) for launch and 10 days thereafter;
plus at least 1 month (need not be contiguous) spread over 1 year
in order to get a full description of the lunar gravity field in terms of
low order spherical harmonics
 - Cat 2: At least 8 hours per day
 - Cat 3: As available
- Availability - Average
 - At least 70 % (90 % goal) over the 1-yr. Nominal Mission, spread evenly
relative to the lunar track (full lunar coverage)
 - At least 8 hr. per day with full command and control capability



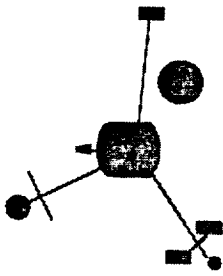
Tracking Requirements - cont'd

— Ground System

LOCKHEED MARTIN



- Uplink
 - Command Rate: 125 bps on 16 kHz subcarrier
 - Coding: BCH (56, 63)
 - EIRP Required: ≥ 55 dBW)
- Downlink
 - Data Rates: 3,600 and 300 bps
 - Bit Error Rate: $\leq 1 \times 10^{-6}$
 - Coding: $R=1/2$, $K=7$ convolutional
 - CCSDS: Level 3
 - Front End G/T: ≥ 18 dB/K (15 dB/K minimum for 3600 bps)

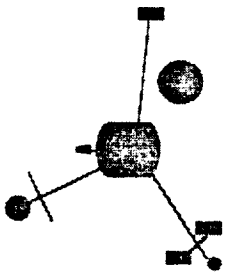


Ground System

Ground Communications Requirements



- Data Circuits (NASCOM 4800): Ground Stations, MCC, GSFC, JPL, WFF
 - Critical Periods (Lau, ΔV , LOI): 2 circuits
 - Nominal Periods (Cruise, On-orbit): 1 circuit
- Voice Circuits: Ground Stations, MCC, GSFC, JPL, WFF
 - Critical Periods: 2 circuits
 - Nominal Periods: 1 circuit
- Call-up Commercial Circuits:
 - As needed by remote terminal users



Mission Control Center (MCC)

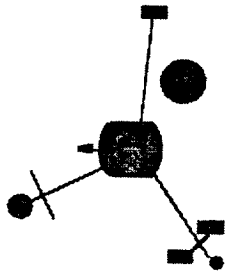
Requirements

— Ground System

LOCKHEED MARTIN



- MCC Location: Ames Research Center, Building N244, Room 301
- Capabilities
 - Perform Command and Control Functions
 - Receive and Archive all Telemetry and Command Data
 - Generate Data Records for PI(s) on CD ROM media
 - Process Data Requests From Local and Remote Work Stations
- Equipment
 - Work Stations: 8 Local, plus 5 Remotes (functions controlled by s/w)
 - Each With:
 - Keyboard
 - Processor
 - CRT Display
 - Networking
 - Data Storage (Fixed & Removable)
 - Voice Comm (phone line for remotes)



Mission Control Center (MCC)

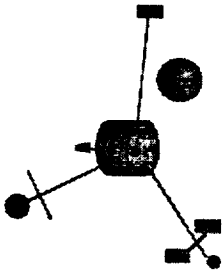
Requirements - cont'd

— Ground System

LOCKHEED MARTIN



- Equipment - cont'd
 - Printers: Local - 2, Remotes 1 each
 - Scanner: Local - 1
 - CD ROM Drives: Local - 1 Read Only & 2 Read/Write
- Staffing: Flight Director (FD)/Assignee Always On-duty or On-call
 - Critical Periods (Launch, ΔV , Orbit Insertion/Changes): 2 Controllers & 6 Subsystem Engineers
 - Normal Ops: 2 Controllers



Navigation & Mission Analysis Requirements

— Ground System

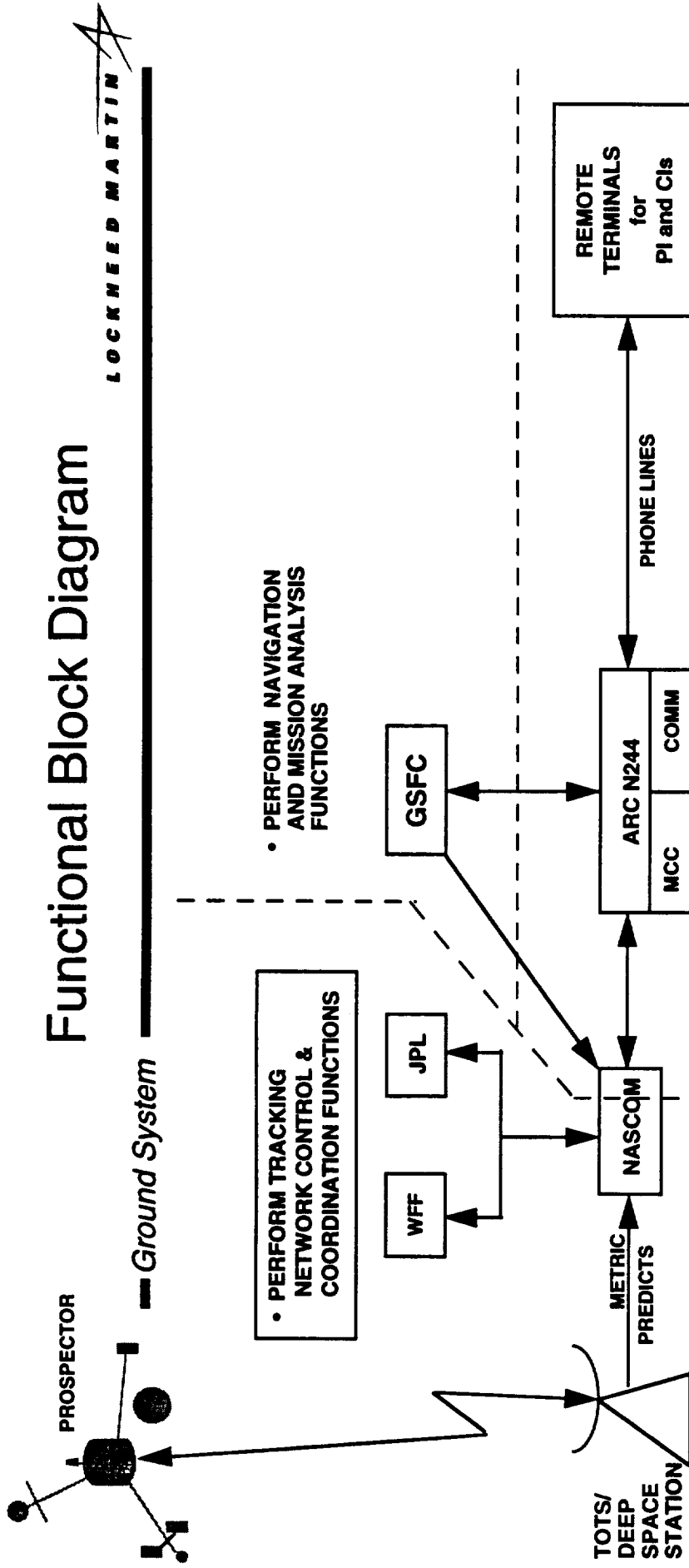
LOCKHEED MARTIN



- Location: Goddard Space Flight Center (GSFC)
- Functions
 - Navigation
 - Process Doppler
 - Generate Orbital Ephemeris
 - Mission Analysis
 - Generate Predicts
 - Support Trajectory Changes and Orbital Maneuvers

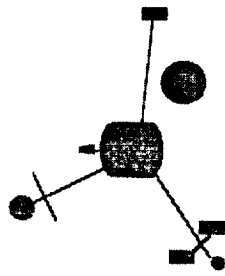
Functional Block Diagram

LOCKHEED MARTIN



TRACKING NETWORK

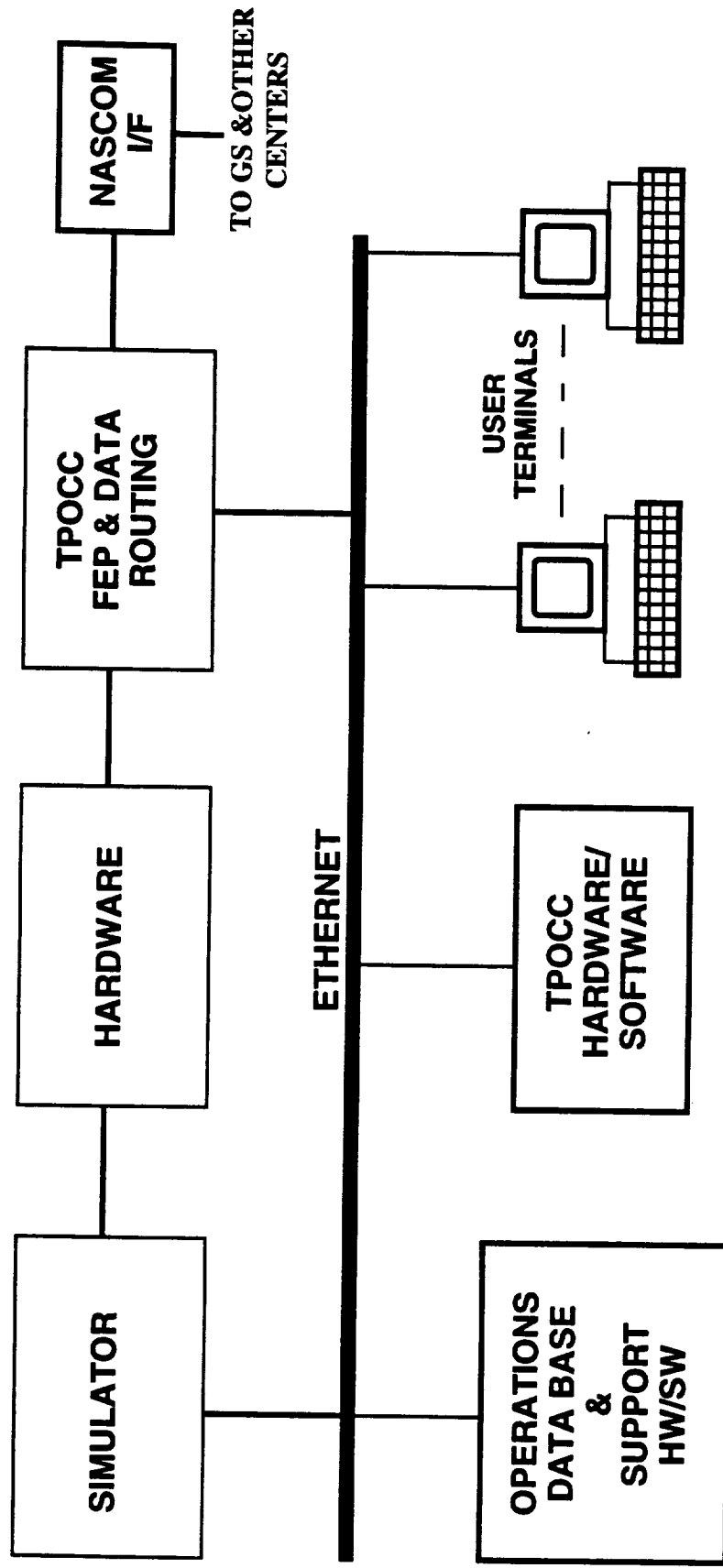
GROUND SYSTEM

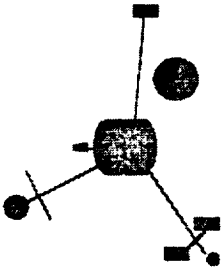


Mission Control Center

— Ground System

LOCKHEED MARTIN



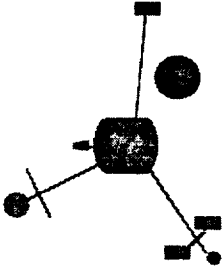


Heritage

LOCKHEED MARTIN

Ground System

- Tracking Network
 - All existing equipment (DSN, TOTS) for command and control, plus for achieving required mission data acquisition
 - New stations planned for Outreach Program only
- Communications
 - Existing NASCOM capabilities for C&C and mission data
 - Phone lines for non-critical remote communications between the Investigators and Mission Control
- Mission Control
 - An adaptation and enhancement of the Pioneer Mission Control Center
 - Maximum utilization of facilities, equipment, and expertise from the Pioneer Project
 - Same approach to common I&T and Mission Control equipment as used on Gravity Probe B

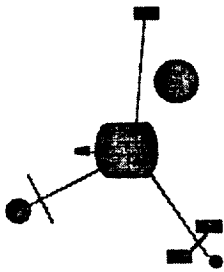


Test and Training Program

— Ground System

LOCKHEED MARTIN

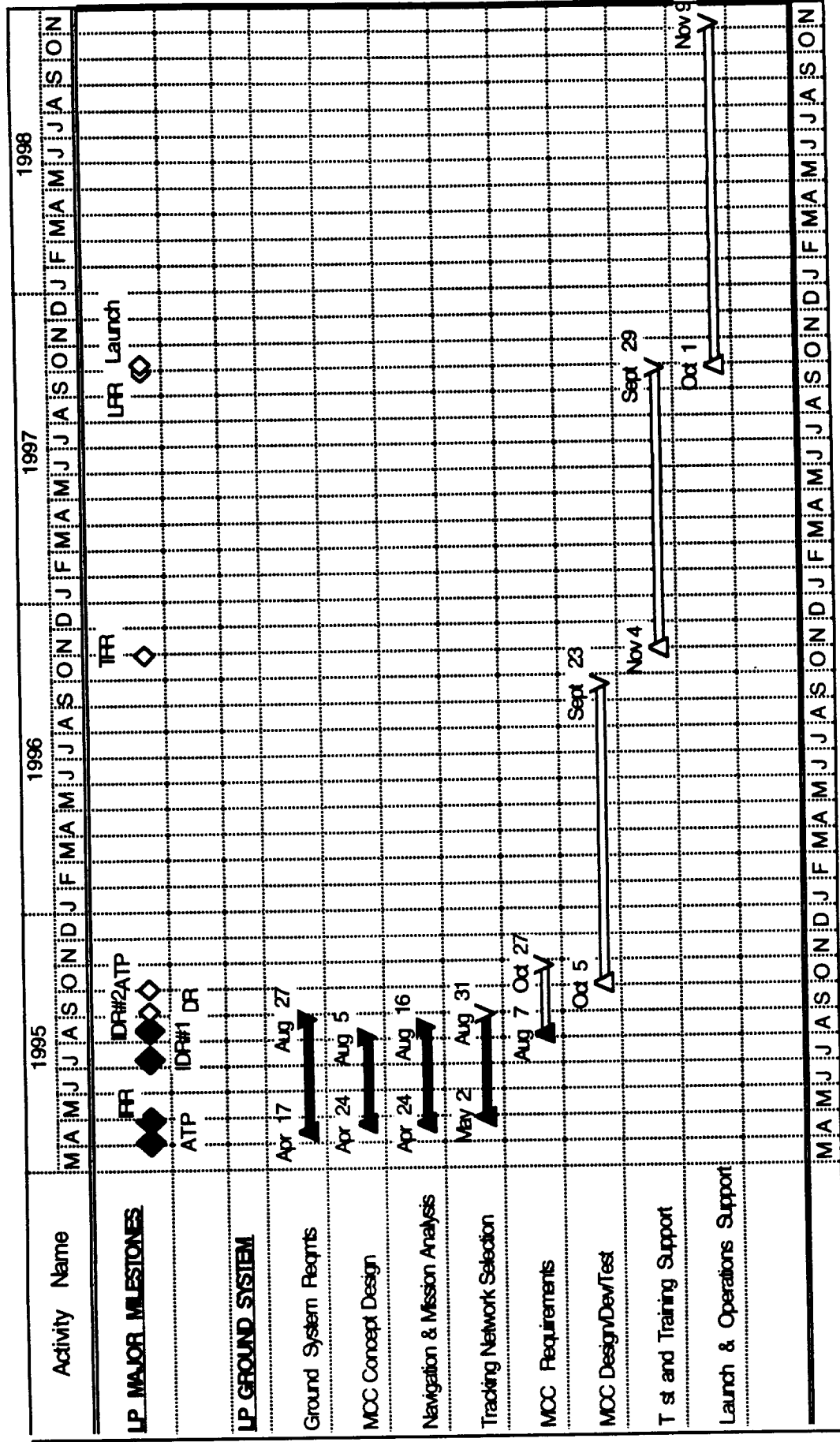
- Full Utilization of the “Design for Operations” Approach
 - Subsystem Engineers become Test Engineers become Flight Operations Engineers
 - Subsystem Test Procedures become I & T System Test Procedures become Flight Operations Procedures
- Software Development System becomes I & T System which is replicated for Flight Operations
- This Method Assures Maximum Training of Personnel and Checkout of Procedures Before Launch
- Spacecraft Simulator is used for initial Flight Operations testing
- Flight Operations participates in system-level I & T testing using actual Flight Procedures for compatibility verification and more realistic training

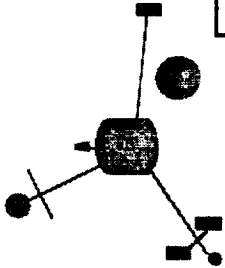


Schedule

— Ground System

LOCKHEED MARTIN





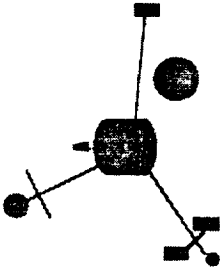
Link Margin - TOTS

-- Ground System

LOCKHEED MARTIN



DOWN LINK			UP LINK		
PARAMETER	VALUE	UNITS	PARAMETER	VALUE	UNITS
FREQUENCY	2.30	GHz	FREQUENCY	2.12	GHz
OUTPUT POWER	6.99	dBW.	OUTPUT POWER	20.97	dBW.
XMT LINE LOSSES	-1.00	dB.	XMT LINE LOSSES	-3.00	dB.
6			(GAIN = 45.00 dB.)		
100			(EFF. = -2.60 dB.)		
ANTENNA GAIN TOTAL	6.00	dB.	ANTENNA GAIN TOTAL	42.40	dB.
POINTING LOSS	0.00	dB.	POINTING LOSS	0.00	dB.
--OTHER LOSSES	0.00	dB.	--OTHER LOSSES--	0.00	dB.
SIGNAL EIRP =	11.99	dBW.	SIGNAL EIRP =	60.37	dBW.
RANGE LOSS	-211.37	dB.	RANGE LOSS	-210.66	dB.
WEATHER LOSS	0.00	dB.	WEATHER LOSS	-1.00	dB.
ATMOSPHERIC LOSS	-1.00	dB.	ATMOSPHERIC LOSS	-0.30	dB.
POLARIZATION LOSS	-0.25	dB.	POLARIZATION LOSS	-0.25	dB.
AUTO-TRACK LOSSES	0.00	dB.	-- COMMENT LOSSES--	0.00	dB.
--OTHER LOSSES	0.00	dB.	-- COMMENT LOSSES	0.00	dB.
SIGNAL RIP =	-200.63	dBW.	SIGNAL RIP =	-151.84	dB.
(GAIN = 45.70 dB.)			(GAIN = 0.00 dB.)		
(EFF. = -2.80 dB.)			(EFF. = -5.23 dB.)		
ANTENNA GAIN TOTAL	42.90	dB.	ANT GAIN	-6.00	dB.
POINTING LOSS	0.00	dB.	POINTING LOSS	0.00	dB.
--OTHER LOSSES--	0.00	dB.	-- OTHER LOSSES	0.00	dB.
FEED RECEIVED SIGNA	-157.73	dBW.	FEED RECEIVED SIGNAL	-157.84	dBW.
RCV LOSS W/BWG GIM	-1.00	dB.	RECEIVE FEED LINE LOSS	-1.00	dB.
SIGNAL AT LNA =	-158.73	dBW.	SIGNAL AT LNA =	-158.84	dBW.
NOISE DENSITY AT LN	-204.81	dBW/Hz.	NOISE DENSITY AT LNA	-198.94	dBW/Hz.
CARRIER/NOISE (C/No)	46.08	dB.-Hz.	CARRIER/NOISE (C/No)=	40.10	dB.-Hz.
DATA NOISE BANDWID	35.56	dB.-Hz.	DATA NOISE BANDWIDTH	20.97	dB.-Hz.
RECEIVED Eb/No =	13.51	dB.	RECEIVED Eb/No =	19.13	dB.
TOTAL REQ'D Eb/No	7.04	dB.	TOTAL REQ'D Eb/No	15.26	dB.
DOWN LINK MARGIN =	6.47	dB.	UP LINK MARGIN =	3.87	dB.



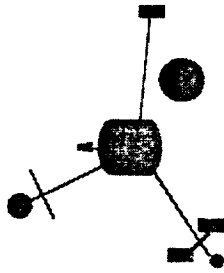
Link Margin - DSN 26m

— Ground System

LOCKHEED MARTIN



DOWNLINK				UPLINK			
PARAMETER	VALUES	UNITS	PARAMETER	VALUES	UNITS		
FREQUENCY	2.30	GHz	FREQUENCY	2.12	GHz		
OUTPUT POWER	6.99	dBW	OUTPUT POWER	20.00	dBW		
XMT LOSS W/BWG GIMBL	-1.00	dB	XMT LOSS W/BWG GIMBL	-3.50	dB		
THEORETICAL GAIN	6.00	dB	THEORETICAL GAIN	55.23	dB		
LOSSES - EFFICIENCY	0.00	dB	LOSSES - EFFICIENCY	-3.72	dB		
ANTENNA GAIN TOTAL	6.00	dB	ANTENNA GAIN TOTAL	51.52	dB		
POINTING LOSS	0.00	dB	POINTING LOSS	-0.27	dB		
--OTHER LOSS	0.00	dB	--OTHER LOSSES--	0.00	dB		
SIGNAL EIRP =	11.99	dBW	SIGNAL EIRP =	67.75	dBW		
RANGE LOSS	-211.38	dB	RANGE LOSS	-210.66	dB		
WEATHER LOSS	0.00	dB	WEATHER LOSS	0.00	dB		
ATMOSPHERIC LOSS	-1.00	dB	ATMOSPHERIC LOSS	0.00	dB		
POLARIZATION LOSS	-0.25	dB	POLARIZATION LOSS	-0.25	dB		
AUTO-TRACK LOSSES	0.00	dB	-- COMMENT LOSSES--	0.00	dB		
--COMMENT LOSSES	0.00	dB	-- COMMENT LOSSES	0.00	dB		
SIGNAL RIP =	-200.64	dBW	SIGNAL RIP =	-143.16	dB		
THEORETICAL GAIN	55.95	dB	THEORETICAL GAIN	0.00	dB		
LOSSES - EFFICIENCY	3.66	dB	LOSSES - EFFICIENCY	0.00	dB		
ANTENNA GAIN TOTAL	52.28	dB	ANT GAIN TOTAL	-10.00	dB		
POINTING LOSS	-0.15	dB	POINTING LOSS	0.00	dB		
--OTHER LOSSES--	0.00	dB	-- OTHER LOSS	0.00	dB		
FEED RECEIVED SIGNAL=	-148.50	dBW	FEED RECEIVED SIGNAL=	-153.16	dBW		
RCV LOSS W/BWG GIMBL	0.10	dB	RCV LOSS W/BWG GIMBL	-1.00	dB		
SIGNAL AT LNA =	-148.40	dBW	SIGNAL AT LNA =	-154.16	dBW		
NOISE DENSITY AT LNA	-208.13	dBW/Hz	NOISE DENSITY AT LNA	-199.77	dBW/Hz		
CARRIER/NOISE (C/No)=	59.73	dB.-Hz	CARRIER/NOISE (C/No)=	45.60	dB.-Hz		
DATA NOISE BANDWIDTH	35.56	dB.-Hz	DATA NOISE BANDWIDTH	20.97	dB.-Hz		
RECEIVED Eb/No =	24.17	dB	RECEIVED Eb/No =	24.63	dB		
TOTAL REQ'D Eb/No	7.40	dB	TOTAL REQ'D Eb/No	0.00	dB		
DOWN LINK MARGIN =	16.77	dB	UP LINK MARGIN =	24.63	dB		



— Ground System

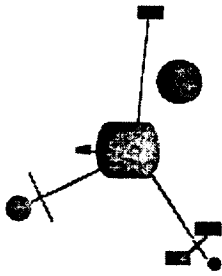
Biography

LOCKHEED MARTIN

- **Thomas L. (Tim) Bridges**, LMMS Responsible Engineer for LP Ground System
 - **Education:** BSEE, BSMath, 22 credits Post-grad toward MSEE
 - **Applicable Experience:** 16 yrs @ NASA ARC on Pioneer Project; Responsible for Mission Operations and Ground Data Systems; ASFOD on Pioneers 6, 7, & 8 and SFOD on 9 & E (bad 2nd stage); Ground Data System Manager for Pioneers 10, 11, 12, & 13 (Jupiter & Venus), and for the ARC portion of IRAS. Over 10 yrs at LMSC: Responsible for computers and data systems on HST and classified programs.
 - **Honors/Awards:** NASA Exceptional Service Medal - For outstanding leadership and contributions to the planning, designing, development, and testing of the Ground Data System used successfully in the tracking, data acquisition, and command for the Pioneer Venus Multiprobe and Orbiter Missions; Also received numerous Group Achievement Awards and SSPs.

13.0 OPERATIONS

A. BINDER



Command and Control

Operations

LOCKHEED MARTIN



- Full operational teams with uplink authority during all critical phases
 - Launch through first 3 days of mapping
 - Orbital maintenance maneuvers
 - Attitude and spin maneuvers
 - Any spacecraft emergencies
- Monitoring teams for all other times
 - No uplink authority
 - Emergency response: Inform PI and on-call flight director
- Support during critical phases
 - S/C engineering team
 - Science team
 - Trajectory team
 - Tracking network engineer

Discovery Archiving

Operations

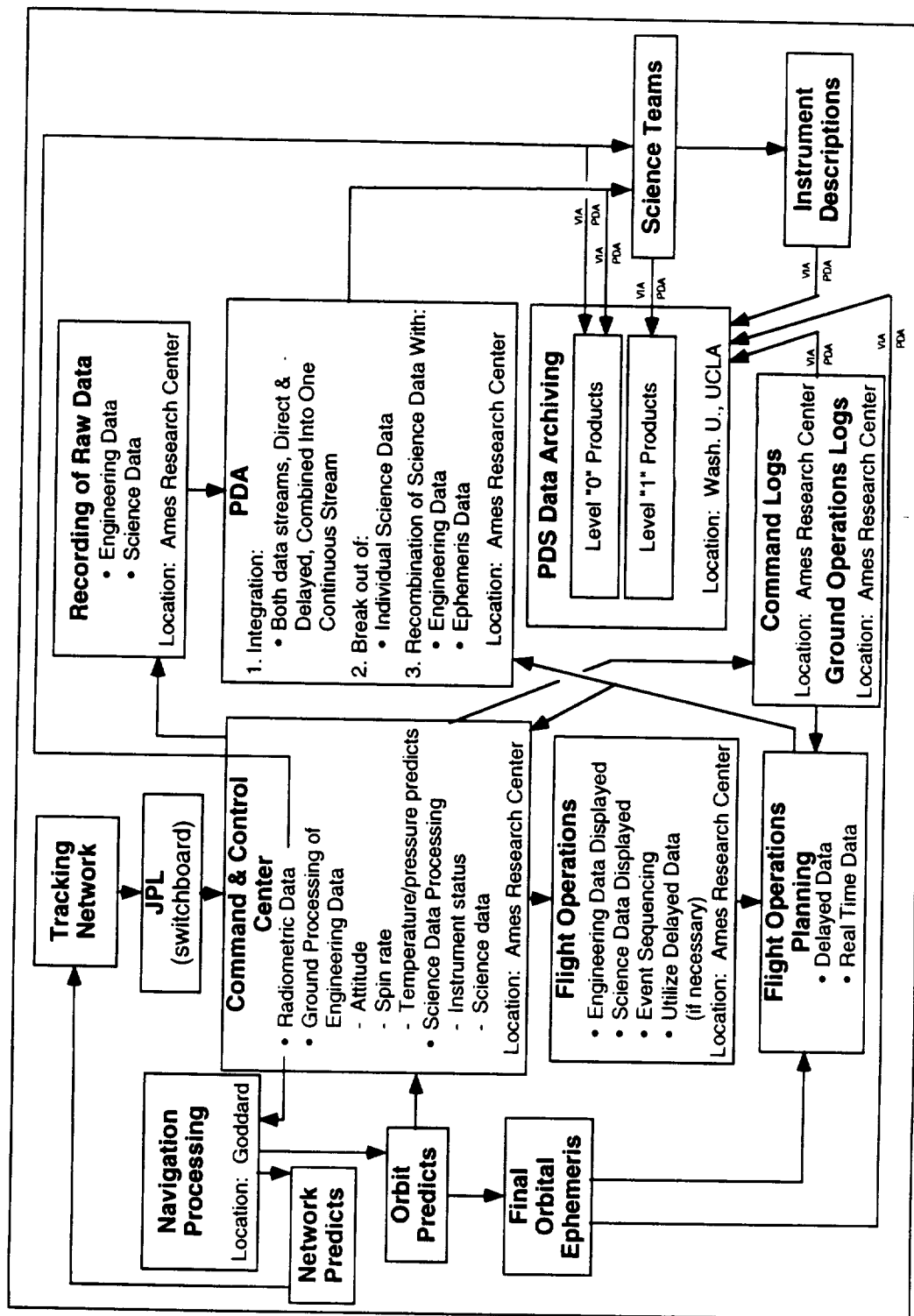
LOCKHEED MARTIN

- "Lunar Prospector Mission data Management Plan" has been released
- Data archived are
 - Science data
 - Engineering data
 - Orbital ephemeris
 - Spacecraft attitude and spin phase
 - Sun crossing times
- Level 0 Data: Time ordered, raw data with 2 downlink streams integrated and corrected for bit errors, organized by instrument
- Level 1 Data:
 - DGS: Spherical harmonics and gravity maps
 - MAG/ER: Corrected time series data in physical units
 - GRS: Integrated spectra, K and Th maps in 5°x5° bins
 - NS: Integrated spectra, thermal and epithermal neutron maps in 5°x5° bins
 - APS: Integrated spectra, Rn and Po maps in 5°x5° bins

Ground Data System

Operations

LOCKHEED MARTIN



Mission Analysis

Operations

LOCKHEED MARTIN



- Trajectory analysis will be done by GSFC
- Mission Planning will be done by the following:
 - PI
 - Science team
 - S/C engineering team
 - Trajectory team
- Tracking
 - Wallops/GSFC for unlink and downlink using:
 - TOTS @ Wallops
 - DSN
 - Dedicated outreach downlink tracking network

14.0 SRM & QA

R. FULLERTON

SRM&QA PLAN

SRM&QA

LOCKHEED MARTIN



- **Total Program Involvement**
- **Quality Assurance program ensures quality is designed and built into every product**
- **Safety engineers identify and mitigate hazards and assure proper protection of personnel and hardware**
- **Previously developed and validated materials, processes, specifications and manufacturing procedures in place**
- **EEE Parts Program reduces risk through rigorous control of non-standard parts**

QUALITY ASSURANCE PLAN

SRM&QA

LOCKHEED MARTIN

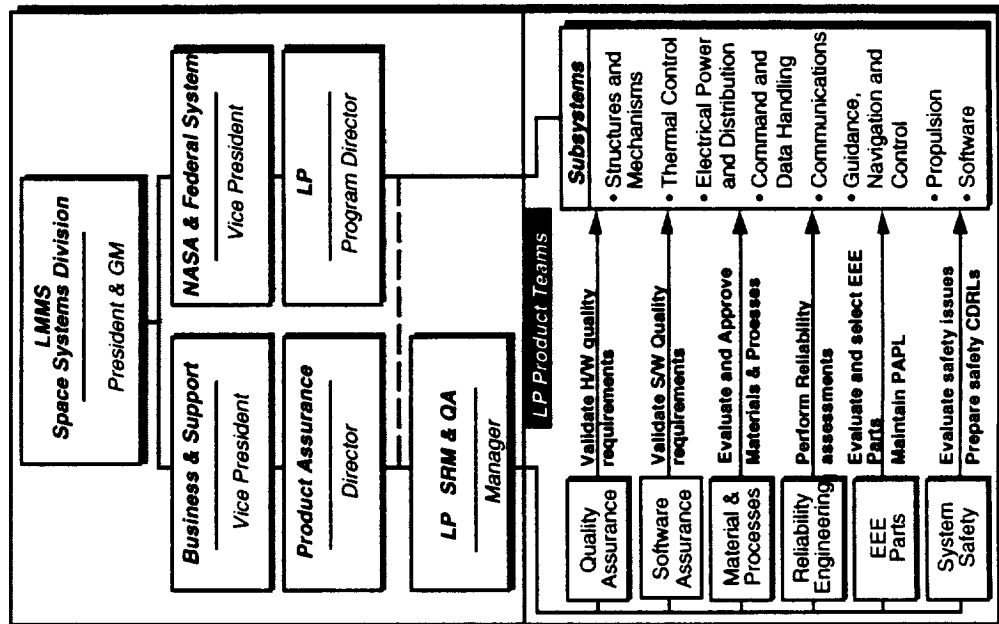


- Independent PA organization
- PA personnel assigned to subsystem
- Build and Test practices per established procedures
- Thorough Verification
- PA personnel support Subcontract
- Procurement Data package review
- Independent audits identify areas for quality improvement.

ORGANIZATION

LOCKHEED MARTIN

SRM&QA



SAFETY PLAN

SRM&QA

LOCKHEED MARTIN



- **Up-front involvement to reduce risk**
- **Design Safety margins**
- **Protection of LP hardware per Program Directive**
- **Validation of vehicle move operations**
- **Environment test facility verifications**
- **Launch Safety Through Launch agreements**
- **Personnel Safety per LMMS procedures**

SAFETY SCHEDULE

SRM&QA

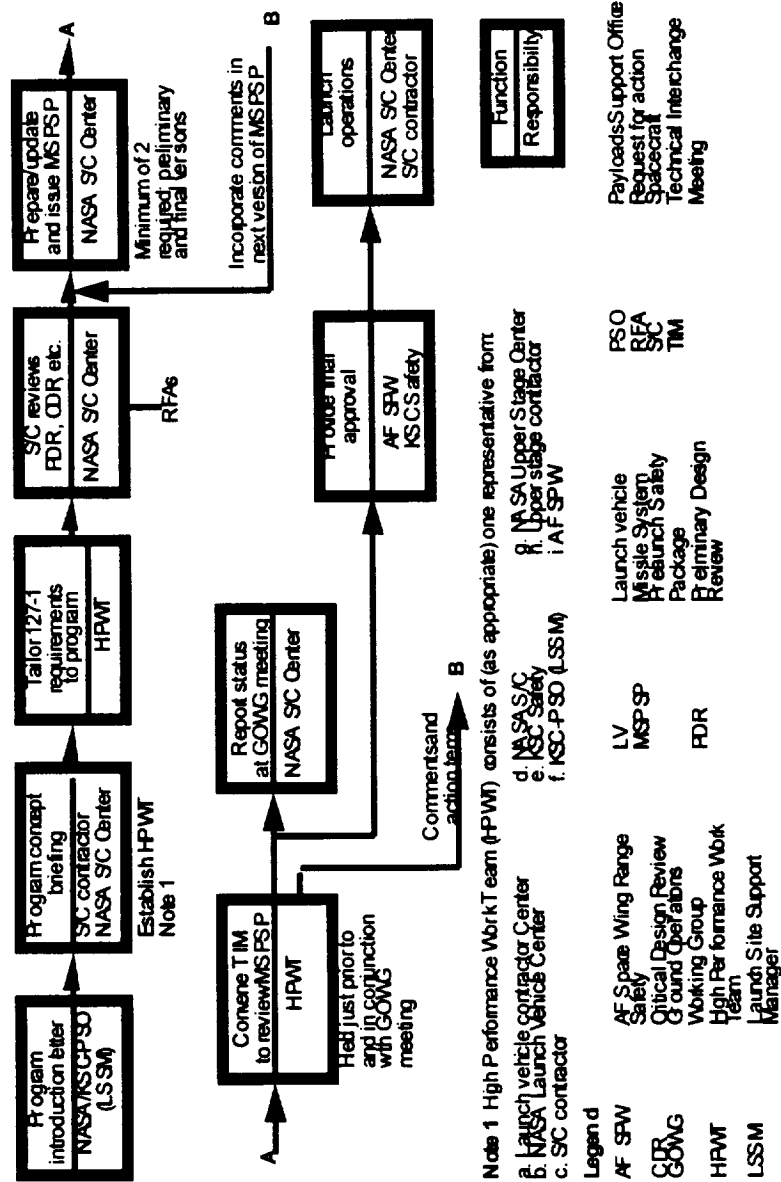
LOCKHEED MARTIN

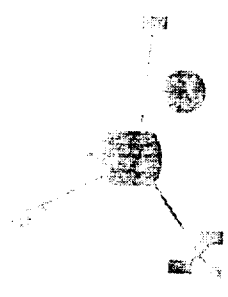
95	1996	1997
Concept Briefing	11/05	
Project Safety Plan	7/02	
Prelim. MSPSP	3/07	
Cat. A Waiver	9/12	12/01
Final MSPSP	10/01	2/01
MSPSP Approv.		
Req'd - KSC		
- AF	3/01	
Ship to KSC	4/15	
Transport to LC-17	5/01	
Launch		6/15
		7/01

Safety Review Process

SRM&QA

LOCKHEED MARTIN





Materials and Processes

SRM&QA

LOCKHEED MARTIN



- State-of-the-art M&P laboratories
- Materials and processes identified for LP are in place
- 250 existing materials and 125 processes meet NASA requirements
- Materials & Processes have flight proven heritage

RELIABILITY PLAN

SRM&QA

LOCKHEED MARTIN



- **PARTS PROGRAM**
 - **Class B Parts**
 - **Maximum use of standard parts**
 - **Control non-standard parts**
 - **On-line NSPAR history file access**
 - **GIDEP Participation**

- **CIRCUIT DESIGN**
 - **Component Stress Analysis**
 - **Sneak Circuit Analysis**
- **TEST**
 - **Component Burn-in**
 - **Extensive Testing at Spacecraft level**
 - **Emphasis on Failure Reporting and Corrective Action**

Part Selection and Screening

SRM&QA

LOCKHEED MARTIN

Priority	Parts Selection Criteria
1	Standard Grade 2 parts
2	Standard Grade 1 parts
3	Monitored Line parts
4	NASA-approved nonstandard parts that meet LP requirements, and on the PAPL
5	Nonstandard parts with flight history requiring NASA approval
6	Nonstandard parts requiring NASA approval

Nonstandard Parts Category	Qualification Method
Monitored Line	Existing qualification data
NASA approved on prior program	Verification of similar mission requirements
Contractor-approved	- Existing qualification data - Flight history - Similarity
Other	Part level qualification test

Parts with Cavities	Screening Method
Microcircuits	MIL-STD-883, Method 2020
Hybrids	MIL-STD-883, Method 2020
Transistors	MIL-STD-750, Method 2052
Diodes	MIL-STD-750, Method 2052
Relays	MIL-R-39016, Appendix B or MIL-STD 202, Method 217
Switches	MIL-STD-202, Method 217
Crystal Oscillators	MIL-STD-883, Method 2020
Thermostats	LMSC/D1420853 or equivalent

15.0 OPPORTUNITIES

A. BINDER/
T. DOUGHERTY

Support for LP/Discovery

■ Outreach

LOCKHEED MARTIN



- Congressional support for LP and Discovery
 - Texas: Gramm, Hutchinson, DeLay, (Brooks, Andrews)
 - California: Rohrabacher, Seastrand, Brown
 - Walker and Sensenbrenner
 - Massive lobbying on LP's behalf by ASA and NSS
 - LP is fully funded in the current budget and set as example of how NASA must perform
- Aerospace States Association (35 states) endorses and supports LP
 - Written members of Walker Committee
 - Member states want to be involved
- National Space Society
 - Lobbies Congress
 - Informs membership and public of LP's progress in "Ad Astra"
- Commercial ventures, LunaCorp, International Space Enterprises and MoonLink, support LP

Congressional Record

Outreach

LOCKHEED MARTIN



●From Congress on LP and Discovery

The Committee commends NASA for continuing the Discovery program to promote low-cost exploration of the solar system, and endorses the program because it is demonstrating a real commitment to innovative management techniques that lower the cost of space exploration. Furthermore, the Discovery program addresses the problems associated with NASA's recent approach to space exploration, which relied on large, expensive spacecraft in development for a decade or more. Consequently, the Committee recommends **full funding for the Lunar Prospector**, a low-cost science probe to the moon which will build on the Defense Department's successful Clementine mission of 1994 and now has a strong educational component provided separately by the private sector. **Lunar Prospector represents the type of resource-leveraging that NASA must perform in an era of constrained budgets.**

Public Awareness

■ Outreach

LOCKHEED MARTIN



- Prior to winning Discovery, LP was the topic in numerous newspaper articles over the previous 6 years
- Publicity since winning Discovery:
 - Major articles in "Ad Astra" Sky and Telescope" and "Astronomy"
 - Major articles in several California newspapers
 - Four interviews on bay area TV
 - Two press releases
- Arranged for LP interactive displays in Museums
 - The Space Center Houston at Johnson Space Center
 - The Tech Museum of Innovation in San Jose, CA
 - Expressions of interest from additional museums
- Public awareness activities will continue to expand

Teacher Science Team Members

Outreach/Education

LOCKHEED MARTIN



- One bay area high school teacher will be chosen to be a science team member for each of the 6 experiments
 - Program is funded by NASA Space Grant
 - Administrated by M., Reesa Abrams, N. CA Space Grant Coordinator
- High school teacher team member duties
 - Participate in science experiment and mission operations
 - Develop science curriculum for grades 10-12
 - Form and lead volunteer teachers team for each experiment
 - Volunteer teachers from all of USA, not just CA
 - beta test science curriculum
 - expand curriculum to lower grades
 - expand curriculum to other subject areas

University and High School Volunteers

■ Outreach/Education

LOCKHEED MARTIN

- Bay area college, university and high school outreach
 - Administrated by M., Reesa Abrams, N. CA Space Grant Coordinator
 - Volunteer student will work in **all** aspects of the program, not just science and engineering
- College and university outreach
 - University of California at Berkeley
 - Stanford University
 - University of Santa Clara
 - California State University San Jose
 - De Anza/Foothill Community Colleges
- High school outreach support
 - University of California Ongoing Summer Program
 - Lockheed Fund for Innovation
 - Lockheed Industry Initiatives for Science and Math Education
 - Berkeley and Oakland High School Summer Program

School Kid Command Controllers

Education

LOCKHEED MARTIN



- MoonLink, Inc. educational program
 - Develop 2 hour classroom/TV exercise
 - Students observe mission control activities (or lack thereof) via live TV in mission control
 - Do a 20-30 minute mission control exercise using LP spacecraft computer model, e.g. do a orbital maintenance burn
 - Question and answer period with off duty controllers, science team members, etc.
 - Conducted during entire mission
 - Will reach >25,000 students in USA and possibly foreign countries

Grad Students and Young Engineers

Education

LOCKHEED MARTIN 

- Co-I Lon Hood, U A
 - Mark Jacobs (MS), working on PhD in Atmospheric Science
- Co-I Robert Lin, UC Berkeley
 - 2 TBD graduate students
- Co-I William Feldman, LANL
 - Michael Miller (BS), working on PhD in Nuclear Eng. at UNM
 - Steve Storms (BS ME, 24), graduate research assistant
 - John Madrid (BS EE, 24) working on MS in EE at UNM-LA
- Co-I Mario Acuna, GSFC
 - 3 to 4 high school through graduate student positions filled each year by the GSFC educational program office

Grad Students and Young Engs (Cont.)

Education

- PM Thomas Dougherty, LMMS
 - Richard Lynch (BS AAE, 27), systems engineer trainee and responsible for TLI stage
 - Francisco Andolz (BS AAE, 26), systems engineer trainee and assisting in propulsion
- David Lozier, Ames
 - Gary Allen, NSF Post-Doc working in trajectory analysis

Small Disadvantage Business

Participation

SDB

LOCKHEED MARTIN



- Howard and Houston - Engineering Support
- Spectrum Astro - C&DH
- Jackson & Tull - Power distribution
- Ed Barnes - Earth/Moon Limb Sensor
- Adcole - Engineering

16.0 RISK MANAGEMENT

T. DOUGHERTY

Risk Management

■ Risk Management

LOCKHEED MARTIN



- C&DH identified as medium risk in proposal.
 - Early procurement initiated, hardware software test program established.
- Subsequent concerns being addressed
- Mitigation plans will be formalized and progress monitored.
- Project manager will continue to identify and assess such areas for mitigation action.

Risk management (cont'd.)

■ Risk Management

LOCKHEED MARTIN



Concerns

Action

- Booster failure

- Alternate suppliers being evaluated.

- Cost growth

- Contingency established.
Configuration control put in place.

- Shock environment

- Soft separation bolts under study

- Magnetics effects on science

- Screening procedures included in program

- Weight growth

- Structure/tank modification

- Power growth

- Added solar array area & contingency

- Antenna development

- Strong similarity to developed unit

Risk Management (cont'd.)

■ Risk Management

LOCKHEED MARTIN

Concerns

Action

- | | |
|------------------------------|---|
| • Short delivery times | • Coordinated with suppliers |
| • Attitude control | • Special stability study |
| • Structure change | • Added stress analysis |
| • Boom mechanism development | • Changed to off-the-shelf deployable boom |
| • Verification | • Retained U.W. for additional test or burn-in. Included sine vibs, accoustics and modal test in program. |

17.0 PROGRAM COST

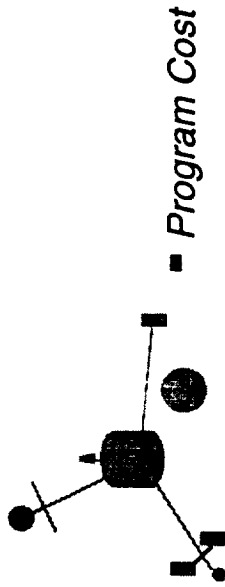
T. DOUGHERTY

Cost Proposal (8/1/95)

■ Program Cost

LOCKHEED MARTIN

- 1411
- Cost and price summary for phases C/D and E
- Funding profile
- Total Mission Cost Summary
- Detailed Cost Summaries at third level by element of cost, fiscal year/
calendar year
- WBS to third level
- Master schedule
- Program Hardware/Software List to fourth level
- Subcontracts: Spreads, Price Analysis
- Priced Bill of Materials: part no., description, quantity, price, supplier,
delivery span
- Person loading at third level: Management, Ops, Systems Engineering,
Q. A., Engineering, Manufacturing, Test, Software
- Organization Task Estimates at third level: Task description, Basis of
Estimates, and W/F spread



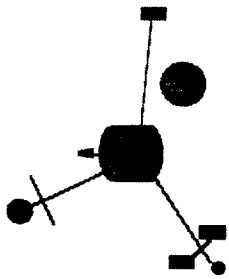
■ Program Cost

Cost Proposal Reduction

LOCKHEED MARTIN



- Transfer stage 200K Better definition
- Thermal subsystem 500K Simplified design for higher temp. NiCd.
- Structure subsystem 200K Boom procurement, existing structure/tooling
- Electrical power 1200K Housewire spacecraft - eliminate firm boards & harness design
Manual box checkout - eliminate test consoles
Combined two distribution boxes



Cost Proposal Reduction (cont'd)

LOCKHEED MARTIN

Program Cost

• Propulsion	100K	Simpler plumbing design, less expensive tanks
• Program Office	1000K	Multidisciplined personnel
• Fee	1200K	Return to original commitment
• Single string	1000K	Eliminated C&DH and Transponder
• Tracking	1700K	Use of TOTS/DSN
• Test span	500K	Test sequence efficiencies
• Subcontracts	500K	Reduction of SDRL's

Program Cost Summary

■ Program Cost

LOCKHEED MARTIN

• Phase B	\$ 2.0M
• Instruments	3.8M
• Labor	5.9M
• Subcontracts	2.3M
• IWT	22.5M
• Material	5.8M
• Travel	.3M
• ODC	3.6M
• OH & G&A	9.5M
• Fee	4.4M
• CAS 414	.9M
• Support	2.1M
• Contingency	1.83M
• Total	\$ 64.93M

Program Cost - Science

Program Cost

LOCKHEED MARTIN

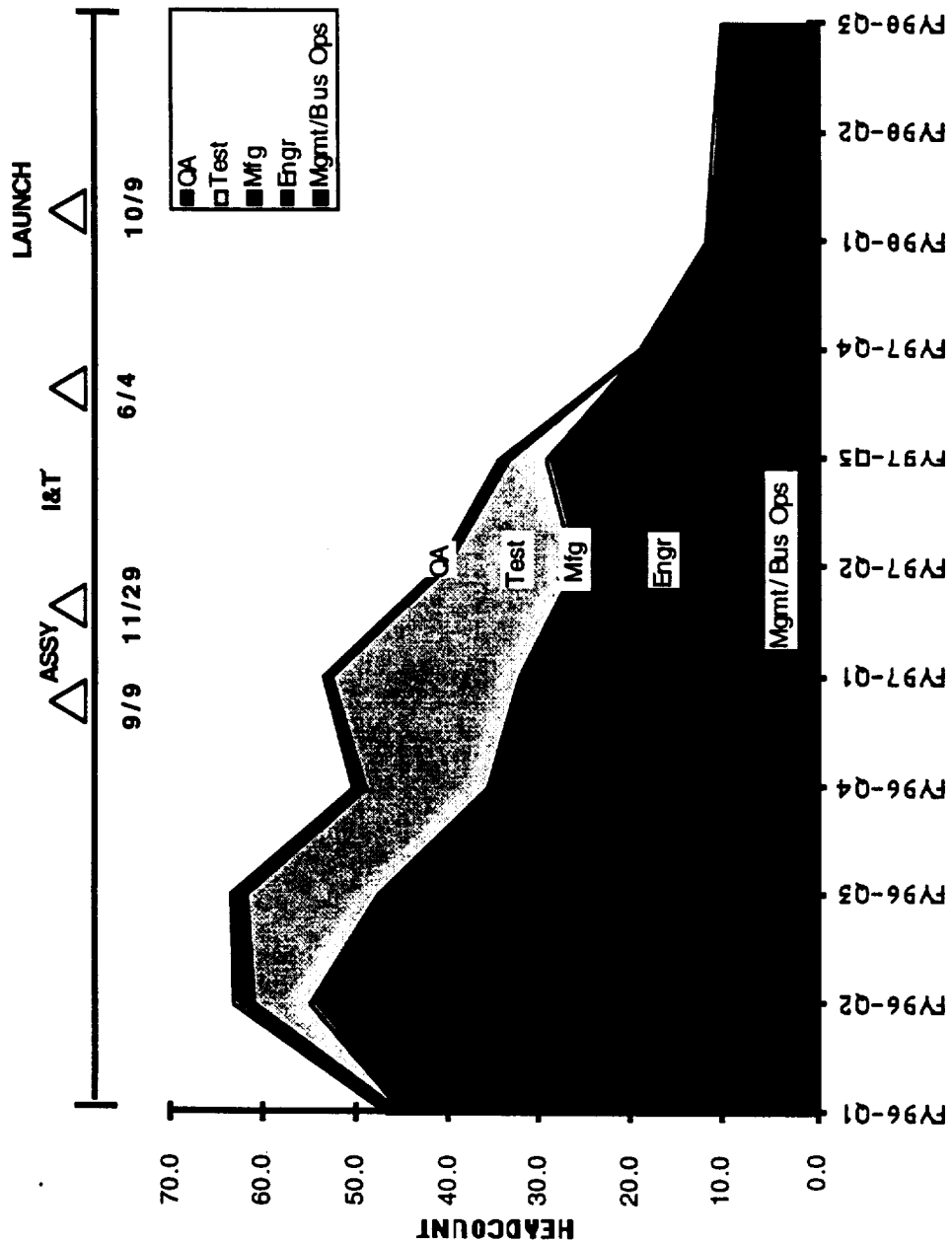


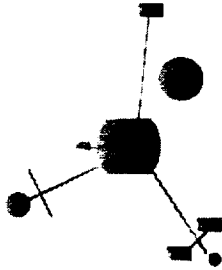
• Spectrometers - Los Alamos/Southwest	\$2.4M
• Magnetometers - University of Arizona	.2M
• Reflectometer - UC Berkeley	.9M
• Doppler gravity - JPL	.3M
Total	\$3.8M

Program Cost - Headcount

LOCKHEED MARTIN

■ Program Cost





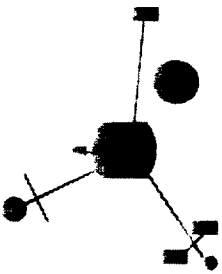
Labor

Program Cost

LOCKHEED MARTIN

Timephased M/M's By WBS

Function	Phase C/D		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY19		FY20		FY21		FY22		FY23		FY24		FY25		FY26		FY27		FY28		FY29		FY30		FY31		FY32		FY33		FY34		FY35		FY36		FY37		FY38		FY39		FY40		FY41		FY42		FY43		FY44		FY45		FY46		FY47		FY48		FY49		FY50		FY51		FY52		FY53		FY54		FY55		FY56		FY57		FY58		FY59		FY60		FY61		FY62		FY63		FY64		FY65		FY66		FY67		FY68		FY69		FY70		FY71		FY72		FY73		FY74		FY75		FY76		FY77		FY78		FY79		FY80		FY81		FY82		FY83		FY84		FY85		FY86		FY87		FY88		FY89		FY90		FY91		FY92		FY93		FY94		FY95		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY19		FY20		FY21		FY22		FY23		FY24		FY25		FY26		FY27		FY28		FY29		FY30		FY31		FY32		FY33		FY34		FY35		FY36		FY37		FY38		FY39		FY40		FY41		FY42		FY43		FY44		FY45		FY46		FY47		FY48		FY49		FY50		FY51		FY52		FY53		FY54		FY55		FY56		FY57		FY58		FY59		FY60		FY61		FY62		FY63		FY64		FY65		FY66		FY67		FY68		FY69		FY70		FY71		FY72		FY73		FY74		FY75		FY76		FY77		FY78		FY79		FY80		FY81		FY82		FY83		FY84		FY85		FY86		FY87		FY88		FY89		FY90		FY91		FY92		FY93		FY94		FY95		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY19		FY20		FY21		FY22		FY23		FY24		FY25		FY26		FY27		FY28		FY29		FY30		FY31		FY32		FY33		FY34		FY35		FY36		FY37		FY38		FY39		FY40		FY41		FY42		FY43		FY44		FY45		FY46		FY47		FY48		FY49		FY50		FY51		FY52		FY53		FY54		FY55		FY56		FY57		FY58		FY59		FY60		FY61		FY62		FY63		FY64		FY65		FY66		FY67		FY68		FY69		FY70		FY71		FY72		FY73		FY74		FY75		FY76		FY77		FY78		FY79		FY80		FY81		FY82		FY83		FY84		FY85		FY86		FY87		FY88		FY89		FY90		FY91		FY92		FY93		FY94		FY95		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY19		FY20		FY21		FY22		FY23		FY24		FY25		FY26		FY27		FY28		FY29		FY30		FY31		FY32		FY33		FY34		FY35		FY36		FY37		FY38		FY39		FY40		FY41		FY42		FY43		FY44		FY45		FY46		FY47		FY48		FY49		FY50		FY51		FY52		FY53		FY54		FY55		FY56		FY57		FY58		FY59		FY60		FY61		FY62		FY63		FY64		FY65		FY66		FY67		FY68		FY69		FY70		FY71		FY72		FY73		FY74		FY75		FY76		FY77		FY78		FY79		FY80		FY81		FY82		FY83		FY84		FY85		FY86		FY87		FY88		FY89		FY90		FY91		FY92		FY93		FY94		FY95		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY19		FY20		FY21		FY22		FY23		FY24		FY25		FY26		FY27		FY28		FY29		FY30		FY31		FY32		FY33		FY34		FY35		FY36		FY37		FY38		FY39		FY40		FY41		FY42		FY43		FY44		FY45		FY46		FY47		FY48		FY49		FY50		FY51		FY52		FY53		FY54		FY55		FY56		FY57		FY58		FY59		FY60		FY61		FY62		FY63		FY64		FY65		FY66		FY67		FY68		FY69		FY70		FY71		FY72		FY73		FY74		FY75		FY76		FY77		FY78		FY79		FY80		FY81		FY82		FY83		FY84		FY85		FY86		FY87		FY88		FY89		FY90		FY91		FY92		FY93		FY94		FY95		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY19		FY20		FY21		FY22		FY23		FY24		FY25		FY26		FY27		FY28		FY29		FY30		FY31		FY32		FY33		FY34		FY35		FY36		FY37		FY38		FY39		FY40		FY41		FY42		FY43		FY44		FY45		FY46		FY47		FY48		FY49		FY50		FY51		FY52		FY53		FY54		FY55		FY56		FY57		FY58		FY59		FY60		FY61		FY62		FY63		FY64		FY65		FY66		FY67		FY68		FY69		FY70		FY71		FY72		FY73		FY74		FY75		FY76		FY77		FY78		FY79		FY80		FY81		FY82		FY83		FY84		FY85		FY86		FY87		FY88		FY89		FY90		FY91		FY92		FY93		FY94		FY95		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY19		FY20		FY21		FY22		FY23		FY24		FY25		FY26		FY27		FY28		FY29		FY30		FY31		FY32		FY33		FY34		FY35		FY36		FY37		FY38		FY39		FY40		FY41		FY42		FY43		FY44		FY45		FY46		FY47		FY48		FY49		FY50		FY51		FY52		FY53		FY54		FY55		FY56		FY57		FY58		FY59		FY60		FY61		FY62		FY63		FY64		FY65		FY66		FY67		FY68		FY69		FY70		FY71		FY72		FY73		FY74		FY75		FY76		FY77		FY78		FY79		FY80		FY81		FY82		FY83		FY84		FY85		FY86		FY87		FY88		FY89		FY90		FY91		FY92		FY93		FY94		FY95		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY19		FY20		FY21		FY22		FY23		FY24		FY25		FY26		FY27		FY28		FY29		FY30		FY31		FY32		FY33		FY34		FY35		FY36		FY37		FY38		FY39		FY40		FY41		FY42		FY43		FY44		FY45		FY46		FY47		FY48		FY49		FY50		FY51		FY52		FY53		FY54		FY55		FY56		FY57		FY58		FY59		FY60		FY61		FY62		FY63		FY64		FY65		FY66		FY67		FY68		FY69		FY70		FY71		FY72		FY73		FY74		FY75		FY76		FY77		FY78		FY79		FY80		FY81		FY82		FY83		FY84		FY85		FY86		FY87		FY88		FY89		FY90		FY91		FY92		FY93		FY94		FY95		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY19		FY20		FY21		FY22		FY23		FY24		FY25		FY26		FY27		FY28		FY29		FY30		FY31		FY32		FY33		FY34		FY35		FY36		FY37		FY38		FY39		FY40		FY41		FY42		FY43		FY44		FY45		FY46		FY47		FY48		FY49		FY50		FY51		FY52		FY53		FY54		FY55		FY56		FY57		FY58		FY59		FY60		FY61		FY62		FY63		FY64		FY65		FY66		FY67		FY68		FY69		FY70		FY71		FY72		FY73		FY74		FY75		FY76		FY77		FY78		FY79		FY80		FY81		FY82		FY83		FY84		FY85		FY86		FY87		FY88		FY89		FY90		FY91		FY92		FY93		FY94		FY95		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY19		FY20		FY21		FY22		FY23		FY24		FY25		FY26		FY27		FY28		FY29		FY30		FY31		FY32		FY33		FY34		FY35		FY36		FY37		FY38		FY39		FY40		FY41		FY42		FY43		FY44		FY45		FY46		FY47		FY48		FY49		FY50		FY51		FY52		FY53		FY54		FY55		FY56		FY57		FY58		FY59		FY60		FY61		FY62		FY63		FY64		FY65		FY66		FY67		FY68		FY69		FY70		FY71		FY72		FY73		FY74		FY75		FY76		FY77		FY78		FY79		FY80		FY81		FY82		FY83		FY84		FY85		FY86		FY87		FY88		FY89		FY90		FY91		FY92		FY93		FY94		FY95		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY19		FY20		FY21		FY22		FY23		FY24		FY25		FY26		FY27		FY28		FY29		FY30		FY31		FY32		FY33		FY34		FY35		FY36		FY37		FY38		FY39		FY40		FY41		FY42		FY43		FY44		FY45		FY46		FY47		FY48		FY49		FY50		FY51		FY52		FY53		FY54		FY55		FY56		FY57		FY58		FY59		FY60		FY61		FY62		FY63		FY64		FY65		FY66		FY67		FY68		FY69		FY70		FY71		FY72		FY73		FY74		FY75		FY76		FY77		FY78		FY79		FY80		FY81		FY82		FY83		FY84		FY85		FY86		FY87		FY88		FY89		FY90		FY91		FY92		FY93		FY94		FY95		FY96		FY97		FY98		FY99		FY00		FY01		FY02		FY03		FY04		FY05		FY06		FY07		FY08		FY09		FY10		FY11		FY12		FY13		FY14		FY15		FY16		FY17		FY18		FY1	
----------	-----------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	-----	--



Program Cost

Labor (Cont'd)

LOCKHEED MARTIN



Timephased M/M's By WBS

Function	Phase C/D		FY96		FY97		FY98		FY99		FY00		C/D	Manmonths
	QTR1	O-D	J-M	A-J	QTR2	A-J	QTR3	J-S	QTR4	O-D	J-M	A-J		
2.3.1-TRACKING NETWORK														
2.3.2-GROUND SYSTEM														
2.3.3-SOFTWARE	4.5				4.5		4.5		3.0		3.0		21.0	21.0
2.3.4-TRAJECTORY ANALYSIS													3.0	25.5
2.4.1-INT, ASSY, TEST & CHECKOUT	3.5				1.0		0.0		0.0		2.0		2.5	10.5
2.4.2-TRANS LUNAR INJECTOR-ENGR	16.5				0.5								1.0	18.0
2.4.2- TRANS LUNAR INJECTOR-MFG	2.0				9.5		11.0		9.0		6.0		4.0	41.5
2.4.2-TRANS LUNAR INJECTOR	18.5				10.0		11.0		9.0		6.0		5.0	59.5
TOTAL	139.3				188.2		190.3		149.8		159.8		102.5	1,052.5

Labor (Cont'd)

Program Cost

LOCKHEED MARTIN

Timephased M/M's By WBS

Function	Phase E FY97		FY98		QTR1		QTR2		QTR3		Phase E		Total
	J-S	QTR4	O-D	J-M	A-J	Manmonths	C/D/E	Manmonths					
1.1.1-PROGRAM MGT	9.0		6.0	6.0	6.0	27.0					90.0		
1.1.1-OPERATIONS	9.0		4.5	4.5	4.5	22.5					121.5		
1.1.1 TOTAL	18.0		10.5	10.5	10.5	49.5					211.5		
2.1.1-SYSTEMS ENGR	12.0		8.0	6.0	4.0	30.0					136.0		
2.1.2-QUALITY ASSUR	1.0					1.0					32.0		
2.1.3-S/C SYS OPERATIONS	1.0					1.0					62.0		
2.1.4-ENGINEERING	1.0					1.0					114.2		
2.1.4-MANUFACTURING	0.0										51.8		
2.1.4-TEST	0.0										192.0		
2.1.4-INT, TEST & CHECKOUT	1.0					1.0					358.0		
2.1.5-ENGINEERING	0.5					0.5					31.8		
2.1.5-MANUFACTURING											6.0		
2.1.5-TEST											5.2		
2.1.5-STRUC/MECHANISMS	0.5					0.5					43.0		
2.1.6-ENGINEERING	0.5					0.5					13.5		
2.1.6-MANUFACTURING											2.5		
2.1.6-TEST											7.5		
2.1.6-THERMAL	0.5					0.5					23.5		
2.1.7-ENGINEERING	0.2					0.2					15.8		
2.1.7-MANUFACTURING	0.0										40.2		
2.1.7-TEST	0.0										5.5		
2.1.7-ELEC POWER	0.2					0.2					61.5		
2.1.8-ENGINEERING	1.0					1.0					22.5		
2.1.8-MANUFACTURING											3.7		
2.1.8-TEST											6.0		
2.1.8-COMM & TRACKING	1.0					1.0					32.2		
2.1.9-COMM & DATA HANDLING	0.5					0.5					25.0		
2.1.10-ATTITUDE CONTROL	0.8					0.8					22.5		
2.1.11-PROPULSION	0.5					0.5					15.3		

Labor (Cont'd)

Program Cost

LOCKHEED MARTIN

Timephased M/M's By WBS

Function	Phase E		FY98		QTR1		QTR2		QTR3		Phase E	Total
	FY97	QTR4	O-D	J-M	A-J	Manmonths	C/D/E	Manmonths				
2.3.1-TRACKING NETWORK		4.0	3.0	3.0	3.0	13.0		13.0			13.0	
2.3.2-GROUND SYSTEM		10.7	10.8	10.7	10.8	43.0		43.0			64.0	
2.3.3-SOFTWARE		1.0	1.0	1.0	0.5	3.5		3.5			29.0	
2.3.4-TRAJECTORY ANALYSIS		3.1	1.5	1.5	1.5	7.6		7.6			7.6	
2.4.1-INT, ASSY, TEST & CHECKOUT		0.5				0.5		0.5			11.0	
2.4.2-TRANS LUNAR INJECTOR-ENGR											18.0	
2.4.2- TRANS LUNAR INJECTOR-MFG											41.5	
2.4.2-TRANS LUNAR INJECTOR											59.5	
TOTAL		56.3	34.8	32.7	30.3	154.1	0.0				1,206.6	

Program Cost - Subcontracts

■ Program Cost

LOCKHEED MARTIN

• Thiokol	\$1.8M
• Dow	\$.5M
Total	\$2.3M

Program Cost - Material

Program Cost

LOCKHEED MARTIN

• C&dh electronics	\$900K
• Limb crossing sensors	\$675K
• Xpndr	\$388K
• Battery	\$312K
• Tanks	\$300K
• Engine	\$258K
• Booms	\$225K
• Solar cells	\$171K
• Hi shear	\$170K

Program Cost - IWT

■ Program Cost

LOCKHEED MARTIN



• Launch services	\$22.0M
• Adaptor	.5M
Total	\$22.5M

Program Costs - Support

LOCKHEED MARTIN

■ Program Cost

GSFC	-	.5M
Ames	-	1.1M
Tracking	-	.5M
Total support	-	\$2.1M

Low Cost Program

LOCKHEED MARTIN

■ Cost

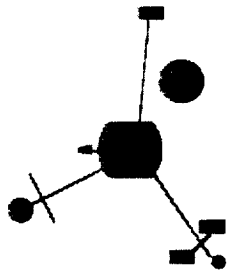
- Simple spacecraft
- Minimum development
- Small, diverse co-located team
- Subsystem ownership
- Minimum participation of support organizations
- Streamlined unobtrusive program controls
- Minimum documentation
- Modern computer capacity
- Iridium i&t heritage
- Design to cost
- Configuration baseline/control
- Budget/schedule reserve

Phase B Completion Plan - 9/29/95

LOCKHEED MARTIN

Issues

- Programmatic
 - Submission of management plan
 - Assign personnel
 - Earned value system
 - ACS and software support definition
 - Increase budget contingency
- (Skill mix, launch reserves, subcontracts, procurement)
- Launch Services
 - Collect data for December decision



Phase B Completion Plan - 9/29/95

■ Issues

(cont.)

LOCKHEED MARTIN



- Prepare for Procurement
 - Structure design
 - Tli procurement package
 - Purchase orders for hardware
 - Redlines for Electrical Power and Thermal Control boxes
 - Purchase orders for material
 - C&DH negotiation
- Science Instruments
 - SRM and QA Audit/Kick-Off

Descope Strategy

■ Descope

- Schedule contingency
- Cost contingency
- Review of test requirements: Acoustic, Sine
Vibration
- Instrument environmental test

18.0 CLOSING REMARKS

A. BINDER/